FINAL ADDENDUM TO THE FINAL SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT REPORT

Raritan Bay Slag Superfund Site
Old Bridge and Sayreville, New Jersey
USACE Contract No. W912DQ-11-D-3004
Task Order No. 004

June 15, 2012

145550
R2-0006752

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Acronyms and Abbreviations

BAF	bioaccumulation factor
BSAF	biota-sediment accumulation factor
COC	contaminant of concern
COPC	chemical of potential concern
CSM	conceptual site model
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ER-L	effects range-low
ER-M	effects range-medium
ERT	Environmental Response Team
ESL	ecological screening level
HQ	hazard quotient
LOAEL	lowest-observed-adverse-effect level
mg/kg	milligram per kilogram
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
NOAEL	no-observed-adverse-effect level
%	percent
PRG	preliminary remedial goal
SFF	site foraging factor
SLERA	screening level ecological risk assessment
SMDP	scientific management decision point
TRV	toxicity reference value
UCL	upper confidence limit
UPL	upper prediction limit

Section 1
Introduction

This document serves as an addendum to the Final Screening Level Ecological Risk Assessment (SLERA) (CDM 2011) conducted for the Raritan Bay Slag Superfund Site located in Old Bridge Township and the Borough of Sayreville, Middlesex County, New Jersey (NJ). Results of the SLERA indicated the potential for ecological risk from a variety of inorganic and organic chemicals present in site media (CDM 2011). The purpose of this supplemental document is to proceed to the next step of the ecological risk assessment process which involves the refinement of chemicals of potential concern (COPCs) identified in the SLERA and further characterizing the potential for risk.

United States Environmental Protection Agency (EPA) guidance recommends using the findings of a SLERA as a basis of a scientific management decision point (SMDP) to determine the next steps in the ecological risk assessment process (EPA 1997). This next step, specifically Step 3a, is conducted in order to refine the list of COPCs that were identified in the SLERA.

1.1 Objectives

The objective of this Step 3a evaluation is to further refine the list of COPCs identified in the SLERA. At this stage in the risk assessment process, less conservative assumptions are used to characterize risks.

This addendum is composed of the following sections along with supporting tables:

Section 1	Introduction – provides an overview of the objectives and organization of the report.
Section 2	Step 3a Approach – discusses the overall approach and less conservative assumptions used in the Step 3a evaluation.
Section 3	Conceptual Site Model – present the conceptual site model (CSM) used in the development of assessment endpoints and associated measurement endpoints.
Section 4	Refined Chemicals of Potential Concern – presents the results of this Step 3a evaluation.
Section 5	Uncertainty Assessment – discusses the uncertainties associated with the assumptions used in this Step 3a evaluation.
Section 6	Summary– summarizes the significant findings of this evaluation.
Section 7	Preliminary Remedial Goal Development – presents the preliminary remedial goals (PRGs) calculated for site-related chemicals posing a risk to molded receptor species.

Section 8	Areas 1, 8, and 9 Results – presents results of the Step 3a evaluation for Areas 1, 8, and 9.
Section 9	Conclusions - presents conclusions of the Step 3a evaluation.
Section 10	References – provides a list of references cited.

Section 2
Step 3a Approach

Areas evaluated in the SLERA consisted of those areas characterized by potential sources of contamination; more specifically, Areas 8 and Area 9. Area 1 was evaluated during a separate investigation by the EPA/Environmental Response Team (EPA/ERT). For Areas 8 and 9, risk to ecological receptors from exposure to chemicals in sediment, soil, and surface water was evaluated. Risk from chemicals present in Area 8 soil was not assessed due to a lack of exposure pathways as almost the entire area is paved, and habitat is extremely limited (CDM 2011).

In the Final SLERA Report, maximum concentrations of chemicals detected in surface soil, sediment, and surface water were compared to ecological screening levels (ESLs). In addition, maximum concentrations of bioaccumulative chemicals detected in Area 9 soil and sediment were evaluated through use of food chain exposure models that incorporated conservative life history and exposure parameters for modeled receptor species. Results of these evaluations indicated the potential for ecological risk from both direct exposure, and through dietary exposure to several inorganic and organic chemicals. A summary of chemicals identified as COPCs can be found in Sections 5.2, 7.1, and 7.2 of the Final SLERA Report (CDM 2011).

In general, a similar approach is taken in this Step 3a evaluation, and focuses on the same areas and media evaluated in the Final SLERA, and in EPA/ERT's investigation. As part of the evaluation, and in order to refine the list of COPCs identified in the SLERA, a less conservative approach is used. As part of this approach, only those chemicals identified as COPCs in the SLERA are further evaluated. Thus, the list of chemicals evaluated in each medium and area either through a comparison to ESLs or, in the case of all bioaccumulative chemicals, through food chain exposure models will differ since risks noted in the SLERA varied between media types, site areas, and modeled receptors. For this evaluation, both means of evaluating risk, either through a comparison to ESLs or through food chain exposure models, are done so following the hazard quotient (HQ) approach as discussed in detail of Sections 5.1.1 and 5.1.2 of the Final SLERA (CDM 2011).

2.1 Comparison to Ecological Screening Levels

In the refined COPC selection, an exposure point concentration (EPC) of the lower of either the 95 percent upper confidence limit (95% UCL) of the arithmetic mean or the maximum detected concentration for each chemical retained as a COPC in the SLERA was calculated. Values used in the calculation of the 95% UCL consisted of those within the same data set evaluated in the SLERA. The resultant EPC values are compared to the same ESLs used in the SLERA with the exception of those used for sediment. In the SLERA, many of the sediment ESLs utilized consisted of New Jersey Department of Environmental Protection (NJDEP) effect range-low (ER-L) values. For the Step 3a evaluation, less conservative effects range-medium (ER-M) values are used when available. Prior to screening, the frequency at which chemicals were detected was taken into account as any chemicals detected in five percent or less of the samples in a dataset of twenty samples or more would be removed from consideration. Tables

2-1 through 2-5 present the EPC values and associated ESLs for each chemical retained in the SLERA as a COPC in its respective media and area (i.e., Area 8 or 9).

Also included in this Step 3a evaluation are the sediment and surface water screening results of EPA/ERT's investigation of Area 1. In EPA/ERT's evaluation, EPC sediment values of select metals were compared to both NJDEP ERL and ERM values. For the purposes of this Step 3a evaluation, only the results of the comparison to ERM values are discussed in order to be consistent with the less conservative approach taken in this evaluation. Surface water data in EPA/ERT's investigation of Area 1 was evaluated through a comparison of EPCs of select metals detected to both acute and chronic surface water ESLs. In keeping with the less conservative approach of this Step 3a evaluation only the results of the comparison to acute values are discussed.

A copy of EPA/ERT's report is provided in Appendix A of this Step 3a evaluation. In addition, Tables 14 and 17 of EPA/ERT's report which present the results of the comparison of sediment and surface water EPCs to their respective ESLs are provided in Exhibit 1 following the tables of this report. A summary of EPA/ERT's investigation is also discussed in Section 2.6 of the Final SLERA (CDM 2011).

2.1.1 Background Concentrations

The conservative approach for selecting COPCs in the SLERA did not consider background concentrations, specifically for metals, even when this data was available. In this Step 3a evaluation, concentrations of metals, represented as the 95% upper prediction limit (UPL) of background samples are also used in the refinement of COPCs (Tables 2-1 through 2-5). When background 95% UPL concentrations for a specific metal exceeded the 95% UCL values used in the evaluation, that metal was eliminated as a COPC. For informational purposes, Area 1 sediment and surface water data, as presented in EPA/ERT's report, was also compared to background 95% UPL concentrations (Table 2-6); however, no chemicals previously identified as COPCs in that risk assessment were eliminated following this approach.

2.2 Food Chain Exposure Models

Similar to the screening exercise noted in Section 2.1, 95% UCL values for media and tissue data were used in the food chain exposure models assessed in the Step 3a evaluation. All soil, sediment, and tissue (where applicable) concentrations consist of the 95% UCL values for those chemicals found in exceedance of no-observed-adverse-effect level (NOAEL) and/or lowest-observed-adverse-effect-level (LOAEL)-based toxicity reference values (TRVs) in the SLERA (SLERA Sections 5.2.2. and 7.2, Tables 5-2 and 5-3, and Appendix D). In addition, the models are run using more representative input parameters such as average reported body weights and food ingestion rates, and more realistic site foraging factors (SFF) for model species that are not expected to reside at the site year long, or utilize 100% for foraging (Table 2-7).

Three additional model receptors, osprey (*Pandion haliaetus*), Canada goose (*Branta canadensis*), and semipalmated plover (*Charadrius semipalmatus*), are also assessed in this Step 3a evaluation (Section 3.1). Sediment and food item (sea lettuce, fish, and mollusk) concentrations used in these models consist of the 95% UCL values calculated using the data collected in support of the EPA/ERT investigation of Area 1 (EPA/ERT 2010) (Table 2-8). For consistency, and due to a limited data set, chemicals evaluated in these additional food chain models are limited to those evaluated in the EPA/ERT investigation.

In keeping with a less conservative approach, all resultant daily doses of chemicals calculated in each model are evaluated through a comparison to their respective LOAEL-based dietary TRV (Tables 2-9 and 2-10); NOAEL-based TRVs are not used in this evaluation. For this Step 3a evaluation the same LOAEL-based TRVs used in the SLERA will be utilized. Biota-sediment accumulation factors (BSAFs) and bioaccumulation factors (BAFs) used in the models to estimate food item concentrations in the absence of site-specific tissue data are presented in Table 2-11.

Section 3
Conceptual Site Model

In the SLERA, the CSM was used to depict the fate and transport of chemicals from source(s) to exposure media (e.g., surface water, sediment, food) and to illustrate potential exposure pathways to ecological receptors. Generally speaking, the CSM developed and presented in Section 2.2 and Figure 2-1 of the SLERA remains unchanged in this Step 3a evaluation as risks were noted for all assessment endpoints that were developed based on the CSM. Those risks are summarized in Sections 5.2, 7.1, and 7.2 of the Final SLERA (CDM 2011).

3.1 Assessment and Measurement Endpoints

In the SLERA, eleven assessment endpoints and associated measurement endpoints were selected to evaluate whether chemicals posed a risk to ecological receptors. Assessment endpoints 1 and 2 were addressed through a comparison of site media chemistry results to ESLs. Assessment endpoint 1 focused on receptors utilizing Area 9 soils, and assessment endpoint 2 evaluated risks to receptors from exposure to sediment and surface water of Areas 8 and 9. In addition, risk from exposure to Area 1 sediment and surface water data will also be included in assessment endpoint 2 of this Step 3a evaluation. Assessment endpoints 3 through 11 were addressed through food chain exposure models using nine receptors representative of avian and mammalian communities assumed to utilize Area 9. These eleven assessment endpoints are re-visited in this Step 3a evaluation with the intent to better refine the list of COPCs unique to each assessment endpoint by following a more representative, and less conservative approach (Sections 2.1 and 2.2).

For this Step 3a evaluation, three additional assessment endpoints, identified as assessment endpoints 12 through 14 are included. These assessment endpoints are aimed at the protection of specific avian communities assumed to be exclusive to and utilize Areas 1 and 8, not Area 9. Similar to the approach followed in the SLERA, Area 1 results will be used as a surrogate to evaluate Area 8 receptors as habitats are similar, and both areas are characterized by the presence of source material. Assessment endpoints 12 and 13, previously evaluated in EPA/ERTs ecological risk assessment (EPA/ERT 2010), address herbivorous and invertivorous birds, while assessment endpoint 14 evaluates piscivorous birds. Although piscivorous birds were evaluated in the SLERA for Area 9 using the belted kingfisher (*Ceryle alcyon*), the osprey was selected to evaluate Area 1. As noted in Section 2.2, sediment and food item concentrations used in these models consist of the 95% UCL of concentrations reported in EPA/ERT's ecological risk assessment report of Area 1 (EPA/ERT 2010).

In summary, the following assessment endpoints and associated measurement endpoints will be included in this Step 3a evaluation:

- Assessment Endpoint 1: Survival, growth, and reproduction of terrestrial organisms (including plants and invertebrates) utilizing Area 9.

  Measurement Endpoint: Further evaluate the toxicity of COPCs in soil by comparing EPCs to soil-specific ESLs.

- Assessment Endpoint 2: Survival, growth, and reproduction of aquatic organisms (including fish and invertebrates) utilizing Areas 1, 8, and 9.

  Measurement Endpoint: Further evaluate the toxicity of COPCs in sediment and surface water by comparing EPCs to sediment- and surface water-specific ESLs.

- Assessment Endpoint 3: Survival, growth, and reproduction of piscivorous birds utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the belted kingfisher, to chemicals in Area 9 sediment through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, site-specific forage fish BSAFs and sediment data, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 4: Survival, growth, and reproduction of piscivorous mammals utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the mink (*Mustela vison*), to chemicals in Area 9 sediment through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, site-specific forage fish BSAFs and sediment data, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 5: Survival, growth, and reproduction of insectivorous birds utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the American robin (*Turdus migratorius*), to chemicals in Area 9 soil through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 6: Survival, growth, and reproduction of insectivorous mammals utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the short-tailed shrew (*Blarina brevicauda*), to chemicals in Area 9 soil through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 7: Survival, growth, and reproduction of carnivorous birds utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the American kestrel (*Falco sparverius*), to chemicals in Area 9 soil through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 8: Survival, growth, and reproduction of carnivorous mammals utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the red fox (*Vulpes vulpes*), to chemicals in Area 9 soil through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 9: Survival, growth, and reproduction of terrestrial herbivorous birds utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the northern bobwhite (*Colinus virginianus*), to chemicals in Area 9 soil through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 10: Survival, growth, and reproduction of terrestrial herbivorous mammals utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the eastern cottontail (*Sylvilagus floridanus*), to chemicals in Area 9 soil through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 11: Survival, growth, and reproduction of aquatic herbivorous mammals utilizing Area 9.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the muskrat (*Ondatra zibethicus*), to chemicals in Area 9 sediment through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 12: Survival, growth, and reproduction of aquatic herbivorous birds utilizing Area 1.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the Canada goose, to chemicals in Area 1 sediment and sea lettuce through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, site-specific sea lettuce and sediment data, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 13: Survival, growth, and reproduction of invertivorous birds utilizing Area 1.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the semipalmated plover, to chemicals in Area 1 sediment and mollusks through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, site-specific mollusk and sediment data, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

- Assessment Endpoint 14: Survival, growth, and reproduction of piscivorous birds utilizing Area 1.

  Measurement Endpoint: Further evaluate daily dietary exposure of the selected receptor species, the osprey, to chemicals in Area 1 sediment and fish through use of a food chain exposure model. The model incorporates representative life history and exposure parameters, site-specific forage fish and sediment data, and compares a calculated daily dietary dose of selected chemicals to their respective LOAEL-based TRVs.

Section 4
Refined Chemicals of Potential Concern

Each of the following subsections present risks to those assessment endpoints assessed in this Step 3a evaluation based on either direct contact or food chain exposure. Chemicals with 95% UCL concentrations above their respective ESLs, or dosed-based TRVs are retained as COPCs. A discussion on the fate and transport of COPCs is provided in Appendix B of the Final SLERA (CDM 2011).

4.1 Direct Contact

Assessment endpoints 1 and 2 are addressed through a comparison of 95% UCL values to ESLs (Section 2.1 and Tables 2-1 through 2-5). Assessment endpoint 1 focuses on receptors in the terrestrial environments of Area 9, while assessment endpoint 2 evaluated risks to receptors in the aquatic environments of Areas 1, 8 and 9.

4.1.1 Assessment Endpoint 1

Assessment endpoint 1, Survival, growth, and reproduction of terrestrial organisms (including plants and invertebrates) utilizing Area 9, is addressed through a comparison of Area 9 95% UCL soil values to ESLs. Based on this comparison, the following COPCs are retained for Area 9 soils:

- PCBs and pesticides: Aroclor 1254 and 4,4'-DDT
- Inorganics: antimony, lead, mercury, tin, and vanadium

4.1.2 Assessment Endpoint 2

Assessment endpoint 2, Survival, growth, and reproduction of aquatic organisms (including fish and invertebrates) utilizing Areas 1, 8, and 9, is addressed through a comparison of Areas 1, 8, and 9 sediment and surface water EPCs. As discussed in Section 2.1, Area 8 and 9 sediment and surface water EPCs are compared to their respective ESLs. Area 1 sediment data is evaluated using EPCs, and Area 1 surface water is evaluated using maximum concentrations as noted in EPA/ERT's report (Appendix A) and provided in Exhibit 1. All three areas are evaluated separately. A summary of COPCs noted for each area is presented in the sections below.

4.1.2.1 Area 9

Sediment: No risks are noted from exposure to Area 9 sediment

Surface Water: Risks are noted from exposure to the following:

- Semi-volatile organic compounds : benzo(a)anthracene
- Inorganics (total and dissolved fractions): copper, iron, lead, manganese and zinc

4.1.2.2 Area 8

Sediment: Risks are noted from exposure to the following:

- Pesticides: 4,4'-DDT, endosulfan II, and endosulfan sulfate
- Inorganics: antimony, arsenic, barium, lead, and manganese

Surface Water: Risks are noted from exposure to the following:

- Inorganics (total and dissolved fractions): arsenic, copper, iron, lead, manganese, vanadium, and zinc

4.1.2.3 Area 1

Sediment: Risks are noted from exposure to the following:

- Inorganics: lead

Surface Water: Risks are noted from exposure to the following:

- Inorganics (dissolved fraction): copper and lead

4.2 Food Chain Exposure Model Risks

The following sections summarize the results of the food chain exposure models. A total of twelve species, each one representing a specific assessment endpoint (Section 2.2) are evaluated. Results of the models are discussed below and presented in Tables 4-1 through 4-12.

4.2.1 Area 9 Soil and Sediment: Assessment Endpoints 3 through 11

Belted kingfisher, mink, and muskrat food chain exposure models were used to evaluate risks to piscivorous bird and mammal, and aquatic herbivorous mammal communities (assessment endpoints 3, 4, and 11, respectively) exposed to Area 9 sediments. Results of the models indicate no risks to any modeled receptor species exposed to Area 9 sediments.

Risks are noted in the short-tailed shrew and American robin models (used to evaluate assessment endpoints 5 and 6) from exposure to the following chemicals in Area 9 soil:

- Short-tailed shrew: pentachlorophenol, Aroclor 1254, and the pesticides alpha-chlordane, endrin, and gamma-chlordane
- American robin: lead, Aroclor 1254, and the pesticides alpha-chlordane, 4,4'-DDT, endrin, and gamma-chlordane

No risks are noted from exposure to Area 9 soil in the northern bobwhite, eastern cottontail, American kestrel, and red fox models representing Area 9 herbivorous bird and mammal, and carnivorous bird and mammal communities (assessment endpoints 7 through 10, respectively).

4.2.2 Area 1 Sediment: Assessment Endpoints 12 through 14

Risks from exposure to lead in Area 1 sediment and mollusks are noted for invertivorous bird communities (assessment endpoint 13) using the semipalmated plover model. No other risks are noted in the semipalmated plover model.

No risks are noted from exposure to Area 1 sediment and food items (fish and sea lettuce) in the Canada goose and osprey models (used to evaluate assessment endpoints 12 and 14) representing Area 1 herbivorous and piscivorous bird communities, respectively.

Based on the results of the Area 1 food chain exposure models, risk to the same receptors present in the aquatic habitats of Area 8 is also assumed as both areas are characterized by similar aquatic habitats, presence of source material, elevated concentrations of metals, and proximity to open water.

Section 5
Uncertainty Assessment

Inherent in the risk assessment process is some degree of uncertainty. Although more realistic assumptions are utilized in this evaluation when compared to the SLERA, there is still a level of uncertainty as discussed below.

In the SLERA, several chemicals detected in Area 8 and 9 media were retained as COPCs due to a lack of ESLs and are summarized in Section 5.2.1 of the SLERA. In this Step 3a evaluation these chemicals are eliminated from further evaluation and are not included in the refined list of COPCs.

In this evaluation, it was assumed that COPCs in environmental media were 100% bioavailable. This is a conservative assumption that overestimates risk. Bioavailability can be affected by factors including chemical speciation, sorption onto soils or sediment, complexation, aging, competition with environmental ligands, or precipitation in anoxic environments in the presence of sulfides (Chapman et al. 2003). Soil and sediment particle size can also influence exposure concentrations and bioavailability; soil/sediment comprised of fine particles will tend to have higher chemical concentrations than coarser textured ones due to the larger surface area and increased number of potential adsorption sites.

Uncertainties can be introduced by use of unrealistic assumptions in the conceptual model. Although this evaluation utilized a less conservative approach when compared to the SLERA, conservative assumptions were still made. Conservative assumptions are generally made in light of the uncertainty associated with the risk assessment process. This minimizes the possibility of concluding that no risk is present when a threat actually does exist (e.g., minimizes false negatives). However, the accuracy with which risk was predicted is not known. The use of conservative assumptions likely overestimates risk.

Marine sediment and surface water ESLs were not always available. In general, and as recommended by the ESL source document, use of freshwater values were used as an alternate. For example, no marine sediment or surface water ESLs for iron or manganese were available so freshwater values were utilized. This approach was followed for several chemicals which are identified in Tables 2-2 through 2-5 in footnotes “a”and “B”.

The recommended dose-based LOAELs presented in Sample *et al*. (1996) for avian and mammalian receptors were derived from an extensive literature review by the authors. These well-accepted values are therefore considered appropriate dose-based TRVs for the receptors modeled in this SLERA. The same assumption applies to TRVs from other sources that were reviewed when no values were available in the Sample *et al*. (1996) document.

This Step 3a, similar to the SLERA, utilized simplifying assumptions in the food chain models, since it is difficult to mimic a complete diet. Thus, for the purpose of the models, receptor species are assumed to only consume a single food item. This is a conservative approach as all modeled receptors are expected to opportunistically consume a wide range of prey/food items, for example, the American robin. A considerable portion of the American robin's diet consists of fruit, especially outside of the breeding season. The assumption that the American robin's diet is comprised solely of soil invertebrates is a conservative assumption.

Site foraging factors for many species used in the food chain exposure models were assumed to be 1.0 or 100 percent as any off site migration either due to life history, foraging behavior, or safe passage is expected to be limited. Only the migratory bird species American robin, osprey, and semipalmated plover, and the American kestrel which has a large foraging range had SFFs adjusted based on territory size or seasonal availability (Table 2-7).

Ecological screening levels and TRVs for certain contaminants were not always available. When applicable, surrogate values were used. In general, these values were those published for a specific parent compound, metabolite or isomer. For example, avian TRVs for 4,4'-DDD and 4,4'-DDE could not be located. Instead, the value for 4,4'-DDT was utilized.

Fish, soil invertebrate, and plant tissue, specific to Area 9 was not collected. In the absence of such data, literature-based BSAF, and BAFs were used to derive hypothetical tissue burden concentrations. Use of these values in the absence of site-specific data is not representative of site conditions, and when used in calculating a daily dietary dose introduces more uncertainties and may over estimate risk.

Sediment-to-biota-accumulation factors were calculated for forage fish which are prey items in the Area 9 kingfisher and mink models. These values were calculated using forage fish and sediment results from EPA/ERTs investigation of Area 1 and were limited to arsenic, copper, lead, and zinc (Table 2-11). These site-specific values are preferred over literature-based values.

Section 6
Summary

Chemicals retained as COPCs in the SLERA were reassessed in this Step 3a evaluation. This section summarizes the results of this evaluation. More specifically, those chemicals which still pose a risk to ecological receptors based on the assessment endpoints identified in Section 3.1.

6.1 Direct Contact

Assessment endpoints 1 and 2 were addressed through a comparison of Areas 8 and 9 sediment and surface water 95% UCL values to ESLs. Area 1 sediment data was evaluated using 95% UCL values; Area 1 surface water was evaluated using maximum concentrations. Assessment endpoint 1 focused on receptors in the terrestrial environments of Area 9, while assessment endpoint 2 evaluated risks to receptors in the aquatic environments of Areas 1, 8, and 9.

6.1.1 Assessment Endpoint 1

Assessment endpoint 1 was addressed through a comparison of Area 9 95% UCL soil values to ESLs. Based on this comparison, the following COPCs are retained in Area 9 soils:

- PCBs and pesticides: Aroclor 1254 and 4,4'-DDT
- Inorganics: antimony, lead, mercury, tin, and vanadium

6.1.2 Assessment Endpoint 2

Assessment endpoint 2 was addressed through a comparison of Area 8 and 9 95% UCL sediment and surface water values to ESLs. Area 1 sediment data was evaluated using 95% UCL values; Area 1 surface water was evaluated using maximum concentrations (Section 2.1). Each area was evaluated separately. A summary of COCs were noted for each area is presented in the sections below.

6.1.2.1 Area 9

Sediment: No risks are noted from exposure to Area 9 sediment

Surface Water: Risks are noted from exposure to the following:

- Semi-volatile organic compounds : benzo(a)anthracene
- Inorganics (total and dissolved fractions): copper, iron, lead, manganese and zinc

6.1.2.2 Area 8

Sediment: Risks are noted from exposure to the following:

- Pesticides: 4,4'-DDT, endosulfan II, and endosulfan sulfate
- Inorganics: antimony, arsenic, barium, lead, and manganese

Surface Water: Risks are noted from exposure to the following:

- Inorganics (total and dissolved fractions): arsenic, copper, iron, lead, manganese, vanadium, and zinc

6.1.2.3 Area 1

Sediment: Risks are noted from exposure to the following:

- Inorganics: lead

Surface Water: Risks are noted from exposure to the following:

- Inorganics (dissolved fraction): copper and lead

6.2 Food Chain Exposure Model Risks

Assessment endpoints 3 through 14 were addressed using food chain exposure models. A total of 12 species, each one representing a specific assessment endpoint aimed at the protection of receptors utilizing Area 9 or Area 1 were evaluated. Similar to the approach followed in the SLERA, Area 1 results were used as a surrogate to evaluate Area 8 receptors as habitats are similar, and both areas are characterized by the presence of source material (Section 3.1).

6.2.1 Area 9 Soil and Sediment: Assessment Endpoints 3 through 11

Based on the results of the belted kingfisher, mink, and muskrat models, no risks are noted for piscivorous bird and mammal, and aquatic herbivorous mammal communities from exposure to chemicals present in Area 9 sediment.

Risks from exposure to the following chemicals in Area 9 soil are noted for insectivorous birds and mammals based on the following models:

- Short-tailed shrew: pentachlorophenol, Aroclor 1254, and the pesticides alpha-chlordane, endrin, and gamma-chlordane

- American robin: lead, Aroclor 1254, and the pesticides alpha-chlordane, 4,4'-DDT, endrin, and gamma-chlordane

Based on the results of the northern bobwhite, eastern cottontail, American kestrel, and red fox models, no risks are noted for terrestrial herbivorous bird and mammal, and carnivorous bird and mammal communities from exposure to chemicals present in Area 9 soil.

6.2.2 Area 1 Sediment: Assessment Endpoints 12 through 14

Risks from exposure to lead in Area 1 sediment and mollusks are noted for invertivorous bird communities based on the semipalmated plover model.

No risks to herbivorous and piscivorous bird communities are noted from exposure to Area 1 sediment and food items (fish and sea lettuce) in the Canada goose and osprey models.

Based on the results of the Area 1 food chain exposure models, risk from exposure to lead to invertivorous bird communities utilizing Area 8 is also assumed as habitats and exposure pathways are similar to those present in Area 1.

Section 7
Preliminary Remedial Goal Development

Risks from exposure to lead, pentachlorophenol, pesticides, and Aroclor 1254 were noted in the food chain exposure models; however, not all the models indicated risks from these chemicals (Section 4.2). Lead was found to be a risk driver in the American robin and semipalmated plover models and is the only chemical for which a PRG is derived. Using the American robin and plover models as a basis, lead PRGs for soil and sediment were calculated as the models evaluate risk from exposure to lead in both media.

Derivation of PRGs was conducted by adjusting the concentrations of lead in soil and sediment until a LOAEL-based HQ of 1.0 was achieved. The resultant lead concentration in sediment or soil was selected as the PRG for that particular medium.

The American robin and semipalmated plover models used in the development of PRGs utilized species-specific input variables (Table 2-7), and literature-based BAFs and site-specific BSAFs (Table 2-11), respectively. As a result, PRGs for lead in soil of 126 milligrams per kilogram (mg/kg) and 401 mg/kg for sediment were calculated (Tables 7-1 and 7-2).

For lead, the proposed site-wide soil PRG is 126 mg/kg and the proposed site-wide sediment PRG is 400 mg/kg. The ecological risk-based PRG developed for soil at 126 mg/kg was calculated using a literature-based BAF. The proposed sediment PRG represents the human health PRG and is also in line with the ecological PRG of 401 mg/kg developed for sediment, which was calculated using a site-specific BSAF. Use of PRGs based on site-specific data is preferred because it is realistic and representative of site conditions.

A single set of unified PRGs was proposed for the site. In this coastal environment along Raritan Bay and in the tidal zone areas, the chemical and physical characteristics of soil and sediment in most cases are indistinguishable. The unified PRG approach was developed in response to concerns that separate medium-specific PRGs for soil and sediment would not be protective in this environment, and that the natural tidal flushing and commingling of soils and sediments would result in cross-contamination if separate remediation goals were implemented. Therefore, a value of 400 mg/kg was selected as the unified lead PRG for both site soils and sediments to be protective of human health and ecological receptors.

Based on the unified lead PRG of 400 mg/kg, portions of Areas 1, 8, and 9 were identified and targeted for removal actions. As noted above, and in Sections 4.1 and 4.2, several organic contaminants were identified in Area 8 soil and Area 9 sediment above screening values; however, PRGs for these compounds were not developed as the potential for risk from these compounds is minimal at most. In general, these compounds were only detected in a small fraction of samples, some of which are situated within the remedial footprint so any risks would be eliminated during removal actions targeting lead. In addition, the conservative nature of the assumptions and methods used to evaluate risk, as noted in the sections below, most likely over-estimate risk.

Section 8
Area 1, 8, and 9 Results

The list of COPCs identified in the SLERA were refined during the Step 3a evaluation; however, risks are still noted for several chemicals.

8.1 Areas 1 and 8

Lead poses a risk to receptors in direct contact with Area 1sediments. Copper and lead (dissolved) pose a risk to receptors exposed to Area 1 surface water.

The metals antimony, arsenic, barium, lead, and manganese, pose a risk to receptors in direct contact with Area 8 sediments.

The pesticides 4,4'-DDT, endosulfan II, and endosulfan sulfate were identified as contaminants of concern in Area 8 sediment through a comparison to ESLs (Section 4.1.2.2). 4,4'-DDT was detected in two out of five samples, and endosulfan II and endosulfan sulfate were detected in one sample. Maximum concentrations for each compound used in the comparison to ESLs were all found within one sample, A8-05, as presented in Table 2-6 of the Final SLERA (CDM 2011). The concentration of the second, and only other detection of 4,4'-DDT was below its ESL. Sample A8-05 is located within the remedial foot print. Any potential for risk from exposure to these compounds will be eliminated during removal activities.

For those receptors in direct contact with Area 8 surface water, the following contaminants of concern were identified: arsenic, copper, iron, lead, manganese, vanadium, and zinc (both total and dissolved fractions).

8.2 Area 9

No risks were identified from dietary exposure to aquatic receptors exposed to Area 9 sediment while foraging for and feeding on fish and aquatic plants.

For those receptors in direct contact with Area 9 surface water, contaminants of concern consist of copper, iron, lead, manganese, and zinc (both total and dissolved fractions).

For those receptors in direct contact with Area 9 soil, such as invertebrates and plants, COPCs include the metals, antimony, lead, mercury, tin, and vanadium and the organics Aroclor 1254 and 4,4'-DDT.

The pesticides, alpha-chlordane, gamma-chlordane, 4,4'-DDT, endrin, and pentachlorophenol, and PCB Aroclor 1254, were identified as COPCs in Area 9 soil based on the American robin and short-tailed shrew food chain exposure models (Section 4.2.1). In order to gain a better understanding of risks from exposure to these compounds, further evaluation was performed.

Both models were rerun using a modified dataset to calculate the 95% UCL exposure point concentration for each of the above chemicals. This dataset excluded outlier data and samples collected within the remedial footprint as any risk from exposure to these chemicals within the remedial area would be eliminated during the removal process. Endrin was eliminated from further evaluation as it was only detected in a single sample that was collected within the removal footprint.

Revised American robin and short-tailed shrew models are presented on Table 8-1. Results of the models indicate no risks from exposure to Aroclor 1254, 4,4'-DDT, and pentachlorophenol. Risks from exposure to alpha-chlordane were noted for both receptors, with a resultant HQ of 1.2 for the short-tailed shrew and 1.8 for the American robin. Only the robin model resulted in an HQ greater than "1" for gamma-chlordance with a HQ of 1.5 (Table 8-1).

In Area 9 soils, insectivorous bird and mammal communities are at risk, a result of higher incidental soil ingestion rates due to feeding habitats and the consumption of soil invertebrates. However, the only site-related risk driver to terrestrial receptors, as indicated in the American robin model, was lead.

Section 9
Conclusions

Hazard quotients in exceedance of "1" were calculated for both the American robin and short-tailed shrew (alpha-chlordane and gamma-chlordane) when evaluating risk from ingestion of organic contaminants; however, higher or lower HQs are not necessarily indicative of more severe or lower effects because of varying degrees of uncertainty in the models and dietary TRVs used to evaluate risks (see Section 5). However, such low values do suggest minimal risks since the daily dose of the chemicals are similar to literature-based effects levels for which they are compared. In addition, both models rely on using literature-based BAFs to determine concentrations of chemicals in prey items (i.e., earthworms), instead of site-specific tissue data, as well as the conservative assumption that all food items consist solely of earthworms/invertebrates. Such conservative dietary assumptions are essentially the "worst case scenario" in terms of exposure as it is expected that other prey/food items make up a considerable portion of each model receptor's diet, especially the American robin. These additional prey/food items may include vegetative material which, in general, does not accumulate organic chemicals such as alpha and gamma-chlordane to any considerable degree when compared to soil invertebrates. Thus, it can be assumed that if a portion of each modeled receptor's diet consisted of vegetation the resultant dose of chemicals consumed would be expected to be lower, and risks unlikely. The use of literature-based values and conservative assumptions most likely over-estimate risks in both models.

In addition, during the SLERA, both alpha- and gamma-chlordane were eliminated as COPCs based on a comparison to ESLs using maximum concentrations. They were only retained and carried through to the food chain exposure models because they are considered bioaccumulative. These conservative assumptions along with HQ values in-line with literature values allowed EPA to conclude that alpha- and gamma-chlordane do not pose an unacceptable ecological risk.

For those receptors in direct contact with Areas 1, 8 and 9 surface water, there were several metal contaminants of concern above screening levels.

Risk from exposure to lead in Area 1 sediment and Area 8 sediment, as modeled through Area 1 sediment, has been identified based upon food chain exposure modeling for the semipalmated plover, an invertivore. Similar to insectivores exposed to Area 9 soil, this is most likely the result of incidental ingestion of sediment due to foraging behavior, as well as sediment entrained in the gut of marine invertebrates on which they feed.

In conclusion, this Step 3a evaluation indicated fewer risks from exposure to chemicals in site media when compared to the SLERA. This is most prevalent for Area 9 where no risks are noted from either direct contact or through dietary exposure of sediments. Of the site-related COPCs, lead is the only risk driver, not only from direct contact, but through dietary exposure in Area 9 soil and Areas 1 and 8 sediments.

Section 10
References

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Table 2-1
Refined Chemicals of Potential Concern Detected in Area 9 Soil
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	CAS No.	EPC[1]	Frequency of Detection	Background Concentration[2]	Screening Value	Hazard Quotient	COPC	Rationale
Semi-volatile Organic Compounds (µg/kg)								
Fluoranthene	206-44-0	150.8	22 / 66	53	1,100 Ac	0.14	No	BSL
Pyrene	129-00-0	192.8	24 / 66	36	1,100 Ac	0.18	No	BSL
Pesticides/PCBs (µg/kg)								
Aroclor 1254	11097-69-1	2553	11 / 66	ND	371 Be	6.9	Yes	ASL
4,4'-DDT	50-29-3	139.8	5 / 66	1.8	21 Ad	6.7	Yes	ASL
Endosulfan II	33213-65-9	280 [3]	3 / 66	ND	119 C	2.4	No	IFD
Inorganic Analytes (mg/kg)								
Antimony	7440-36-0	15.6	37 / 110	0.2	0.27 A	58	Yes	ASL
Arsenic	7440-38-2	15.07	106 / 110	3.1	18 A	0.84	No	BSL
Cadmium	7440-43-9	0.177	58 / 110	0.026	0.36 A	0.49	No	BSL
Chromium	7440-47-3	9.959	110 / 110	7.8	26 Aa	0.38	No	BSL
Copper	7440-50-8	27.8	106 / 110	2.2	28 A	0.99	No	BSL
Lead	7439-92-1	612.5	105 / 110	5.7	11 A	56	Yes	ASL
Manganese	7439-96-5	69.4	110 / 110	20.9	220 A	0.32	No	BSL
Mercury	7439-97-6	0.0976	52 / 67	ND	0.00051 B	191	Yes	ASL
Selenium	7782-49-2	0.438	37 / 110	0.095	0.52 A	0.84	No	BSL
Silver	7440-22-4	0.921	30 / 110	ND	4.2 A	0.22	No	BSL
Tin	7440-31-5	313 [3]	2 / 5	NA	50 B	6.3	Yes	ASL
Vanadium	7440-62-2	17.86	108 / 110	10.5	7.8 A	2.3	Yes	ASL
Zinc	7440-66-6	43.1	90 / 110	15	46 A	0.94	No	BSL

Notes:

1 - value consists of the 95% Upper Confidence Level (UCL) of Area 9 soil samples evaluated in the screening level ecological risk assessment (SLERA).

2 - background concentrations consist of the 95% Upper Prediction Limit (UPL) as calculated in the SLERA.

3 - maximum detected concentration used when less than four samples were detected in the dataset.

µg/kg - micrograms per kilogram

mg/kg - milligrams per kilogram

ASL - above screening level

BSL - equal to or below screening level

COPC - chemical of potential concern

EPC - exposure point concentration

IFD - infrequent detection

NA - chemical not analyzed in background samples

ND - chemical not detected in background samples

A - EPA Ecological Soil Screening Levels (EcoSSLs). http://www.epa.gov/ecotox/ecossl/

B -Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones. 1997. Preliminary Remediation Goals (PRGs) for Ecological Endpoints. Prepared for the U.S. Department of Energy, Office of Environmental Management Contract No. DE-AC05-84OR21401.

C -EPA 2003. EPA Region 5 Resource Conservation and Recovery Act (RCRA) Ecological Screening Levels.

a - value for chromium (trivalent)

c - value for high molecular weight polycyclic aromatic hydrocarbons

d - value for DDT and metabolites

e - value for PCBs

Table 2-2
Refined Chemicals of Potential Concern Detected in Area 9 Sediment
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	CAS No.	EPC[1]	Frequency of Detection	Background Concentration[2]	Screening Value	Hazard Quotient	COPC	Rationale
Semi-volatile Organic Compounds (µg/kg)								
Acenaphthene	83-32-9	10.65	7 / 39	ND	500 A	0.02	No	BSL
Acenaphthylene	208-96-8	16.74	19 / 39	10.1	640 A	0.03	No	BSL
Anthracene	120-12-7	95 [3]	2 / 39	ND	1100 A	0.09	No	BSL
Benzo(a)anthracene	56-55-3	206.8	36 / 39	136.8	1600 A	0.13	No	BSL
Benzo(a)pyrene	50-32-8	150.6	36 / 39	60.5	1600 A	0.09	No	BSL
Benzo(g,h,i)perylene	191-24-2	159.5	7 / 39	ND	170 B	0.94	No	BSL
Benzo(k)fluoranthene	207-08-9	174.8	8 / 39	ND	240 B	0.73	No	BSL
Chrysene	218-01-9	204.2	36 / 39	93	2800 A	0.07	No	BSL
Dibenzo(a,h)anthracene	53-70-3	18.2	19 / 39	13.3	260 A	0.07	No	BSL
Fluoranthene	206-44-0	313.6	18 / 39	160	5100 A	0.06	No	BSL
Fluorene	86-73-7	7.288	9 / 39	ND	540 A	0.01	No	BSL
Indeno(1,2,3-cd)pyrene	193-39-5	156	7 / 39	43	200 B	0.78	No	BSL
Naphthalene	91-20-3	320 [3]	1 / 39	130	2100 A	0.15	No	BSL
Phenanthrene	85-01-8	147.1	6 / 39	ND	1500 A	0.10	No	BSL
Pyrene	129-00-0	259	18 / 39	130	2600 A	0.10	No	BSL
Pesticides/PCBs (µg/kg)								
Alpha-Chlordane	5103-71-9	9.2 [3]	2 / 39	ND	7 Bc	1.3	No	IFD
Inorganic Analytes (mg/kg)								
Antimony	7440-36-0	1.697	5 / 72	2	9.3 A	0.18	No	BSL, BCK
Arsenic	7440-38-2	14.37	72 / 72	38.7	70 A	0.21	No	BSL, BCK
Barium	7440-39-3	26.67	37 / 72	31.3	48 A	0.56	No	BSL, BCK
Cadmium	7440-43-9	0.672	24 / 72	0.69	9.6 A	0.07	No	BSL, BCK
Copper	7440-50-8	92.83	72 / 72	176	270 A	0.34	No	BSL, BCK
Iron	7439-89-6	30846	72 / 72	37580	20000 Ca	1.5	No	BCK
Lead	7439-92-1	139.9	63 / 72	181.5	218 A	0.64	No	BSL, BCK
Mercury	7439-97-6	0.477	45 / 46	0.88	0.71 A	0.67	No	BSL, BCK
Nickel	7440-02-0	26.14	69 / 72	22	52 A	0.50	No	BSL
Selenium	7782-49-2	1.03	24 / 72	1.9	1.0 A	1.0	No	BCK
Silver	7440-22-4	2.015	26 / 72	1.3	3.7 A	0.54	No	BSL
Vanadium	7440-62-2	40.04	71 / 72	72.2	57 A	0.70	No	BSL, BCK
Zinc	7440-66-6	79.52	72 / 72	143.5	410 A	0.19	No	BSL, BCK

Notes:

1 - value consists of the 95% Upper Confidence Level (UCL) of Area 9 sediment samples evaluated in the screening level ecological risk assessment (SLERA).

2 - background concentrations consist of the 95% Upper Prediction Limit (UPL) as calculated in the SLERA.

3 - maximum detected concentration used when less than four samples were detected in the dataset.

µg/kg - micrograms per kilogram

mg/kg - milligrams per kilogram

BCK - background concentration higher than value evaluated

BSL - equal to or below screening level

COPC - chemical of potential concern

EPC - exposure point concentration

IFD - infrequent detection

ND - chemical not detected in background samples

A - New Jersey Site Remediation Program. 2009. Marine/Estuarine Sediment Screening Guidelines. Effects Range-Medium (ER-M) values

B - no marine ER-M or ER-L available; freshwater ER-L used

C - EPA 2006. EPA Region 3 Biological Technical Assistance Group Marine Sediment Screening Benchmarks,
Mid-Atlantic Risk Assessment: Ecological Risk Assessment, http://www.epa.gov/reg3hwmd/risk/eco/index.htm

a - freshwater value used as directed by reference

c - value for chlordane

Table 2-3
Refined Chemicals of Potential Concern Detected in Area 9 Surface Water
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	CAS No.	EPC[1]	Frequency of Detection	Background Concentration[2]	Screening Value	Hazard Quotient	COPC	Rationale
Semi-volatile Organic Compounds (µg/L)								
Benzo(a)anthracene	56-55-3	0.053 [3]	1 / 17	ND	0.018 Ca	2.9	Yes	ASL
Inorganic Analytes (Total) (µg/L)								
Copper	7440-50-8	21.91	7 / 30	ND	3.1 A*	7.1	Yes	ASL
Iron	7439-89-6	10846	20 / 30	ND	300 Ca	36	Yes	ASL
Lead	7439-92-1	76.39	8 / 30	ND	24 A*	3.2	Yes	ASL
Manganese	7439-96-5	272.6	25 / 30	73.7	120 Ca	2.3	Yes	ASL
Zinc	7440-66-6	88.11	10 / 30	ND	81 A*	1.1	Yes	ASL
Inorganic Analytes (Dissolved) (µg/L)								
Copper	7440-50-8	21.37	7 / 32	ND	3.1 A*	6.9	Yes	ASL
Iron	7439-89-6	14494	14 / 32	ND	300 Ca	48	Yes	ASL
Lead	7439-92-1	282 [3]	2 / 32	ND	24 A*	11.8	Yes	ASL
Manganese	7439-96-5	297.4	26 / 32	ND	120 Ca	2.5	Yes	ASL
Zinc	7440-66-6	151	5 / 32	ND	81 A*	1.9	Yes	ASL

Notes:

1 - value consists of the 95% Upper Confidence Level (UCL) of Area 9 surface water samples evaluated in the screening level ecological risk assessment (SLERA).

2 - background concentrations consist of the 95% Upper Prediction Limit (UPL) as calculated in the SLERA.

3 - maximum detected concentration used when less than four samples were detected in the dataset.

µg/L - micrograms per liter

ASL - above screening level

COPC - chemical of potential concern

EPC - exposure point concentration

ND - chemical not detected in background samples

A -NJDEP 2011. Surface Water Quality Standards, Saline Water Chronic Values, January 2011, downloaded January 24, 2011

C -EPA 2006. EPA Region 3 Biological Technical Assistance Group Marine Screening Benchmarks,
Mid-Atlantic Risk Assessment: Ecological Risk Assessment, http://www.epa.gov/reg3hwmd/risk/eco/index.htm

*-dissolved criteria

a - freshwater value is used as directed by EPA

Table 2-4
Refined Chemicals of Potential Concern Detected in Area 8 Sediment
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	CAS No.	EPC[1]	Frequency of Detection	Background Concentration[2]	Screening Value	Hazard Quotient	COPC	Rationale
Pesticides/PCBs (µg/kg)								
Aroclor 1254	11097-69-1	720 [3]	3 / 5	ND	34000 Aa	0.02	No	BSL
4,4'-DDT	50-29-3	96 [3]	2 / 5	ND	7 A	14	Yes	ASL
Endosulfan II	33213-65-9	36 [3]	1 / 5	ND	14 Ca	2.6	Yes	ASL
Endosulfan Sulfate	1031-07-8	24 [3]	1 / 5	ND	0.357 C	67	Yes	ASL
Gamma-Chlordane	5103-74-2	52 [3]	1 / 5	ND	6000 Bc	0.01	No	BSL
Inorganic Analytes (mg/kg)								
Antimony	7440-36-0	259.8	41 / 57	2.0	9.3 A	28	Yes	ASL
Arsenic	7440-38-2	113.8	56 / 57	38.7	70 A	1.6	Yes	ASL
Barium	7440-39-3	150.5	51 / 57	31.3	48 A	3.1	Yes	ASL
Cadmium	7440-43-9	2.331	36 / 57	0.69	9.6 A	0.24	No	BSL
Chromium	7440-47-3	348.5	57 / 57	75.1	370 A	0.94	No	BSL
Copper	7440-50-8	123.2	56 / 57	176	270 A	0.46	No	BSL, BCK
Iron	7439-89-6	23771	55 / 57	37580	20000 Ca	1.2	No	BCK
Lead	7439-92-1	2340	53 / 57	181.5	218 A	11	Yes	ASL
Manganese	7439-96-5	295.6	56 / 57	185.1	260 A	1.1	Yes	ASL
Mercury	7439-97-6	0.536	42 / 44	0.88	0.71 A	0.75	No	BSL, BCK
Nickel	7440-02-0	17.62	56 / 57	22	52 A	0.34	No	BSL, BCK
Selenium	7782-49-2	0.849	40 / 57	1.9	1.0 A	0.85	No	BSL, BCK
Silver	7440-22-4	0.903	41 / 57	1.3	3.7 A	0.24	No	BSL, BCK
Vanadium	7440-62-2	28.43	57 / 57	72.2	57 A	0.50	No	BSL, BCK
Zinc	7440-66-6	342.4	56 / 57	143.5	410 A	0.84	No	BSL

Notes:

1 - value consists of the 95% Upper Confidence Limit (UCL) of Area 8 sediment samples evaluated in the screening level ecological risk assessment (SLERA).

2 - background concentrations consist of the 95% Upper Prediction Limit (UPL) as calculated in the SLERA.

3 - maximum detected concentration used when less than four samples were detected in the dataset.

µg/kg - micrograms per kilogram

mg/kg - milligrams per kilogram

ASL - above screening level

BCK - background concentration higher than value evaluated

BSL - equal to or below screening level

COPC - chemical of potential concern

EPC - exposure point concentration

ND - chemical not detected in background samples

A - New Jersey Site Remediation Program. 2009. Marine/Estuarine Sediment Screening Guidelines. Effects Range-Medium (ER-M) values

B - no marine ER-M or ER-L available; freshwater ER-L used

C - EPA 2006. EPA Region 3 Biological Technical Assistance Group Marine Sediment Screening Benchmarks, Mid-Atlantic Risk Assessment: Ecological Risk Assessment, http://www.epa.gov/reg3hwmd/risk/eco/index.htm

a - freshwater value used as directed by reference

c - value for chlordane

Table 2-5
Refined Chemicals of Potential Concern Detected in Area 8 Surface Water
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	CAS No.	EPC[1]	Frequency of Detection	Background Concentration[2]	Screening Value	Hazard Quotient	COPC	Rationale
Inorganic Analytes (Total) (µg/L)								
Arsenic	7440-38-2	44.2	5 / 12	ND	36 A*	1.2	Yes	ASL
Copper	7440-50-8	154 [3]	2 / 12	ND	3.1 A*	50	Yes	ASL
Iron	7439-89-6	2278	4 / 12	ND	300 Ca	7.6	Yes	ASL
Lead	7439-92-1	675	4 / 12	ND	24 A*	28	Yes	ASL
Manganese	7439-96-5	206.8	4 / 12	73.7	120 Ca	1.7	Yes	ASL
Vanadium	7440-62-2	65.2 [3]	1 / 12	ND	20 Ca	3.3	Yes	ASL
Zinc	7440-66-6	255 [3]	2 / 12	ND	81 A*	3.1	Yes	ASL
Inorganic Analytes (Dissolved) (µg/L)								
Arsenic	7440-38-2	49.79	5 / 12	ND	36 A*	1.4	Yes	ASL
Copper	7440-50-8	197 [3]	2 / 12	ND	3.1 A*	64	Yes	ASL
Iron	7439-89-6	2763	4 / 12	ND	300 Ca	9.2	Yes	ASL
Lead	7439-92-1	1810 [3]	3 / 12	ND	24 A*	75	Yes	ASL
Manganese	7439-96-5	215.9	4 / 12	ND	120 Ca	1.8	Yes	ASL
Nickel	7440-02-0	20.08	4 / 12	ND	22 A*	0.91	No	BSL
Vanadium	7440-62-2	63.8 [3]	1 / 12	ND	20 Ca	3.2	Yes	ASL
Zinc	7440-66-6	363 [3]	2 / 12	ND	81 A*	4.5	Yes	ASL

Notes:

1 - value consists of the 95% Upper Confidence Limit (UCL) of Area 8 surface water samples evaluated in the screening level ecological risk assessment (SLERA).

2 - background concentrations consist of the 95% Upper Prediction Limit (UPL) as calculated in the SLERA.

3 - maximum detected concentration used when less than four samples were detected in the dataset.

µg/L - micrograms per liter

ASL - above screening level

BSL - equal to or below screening level

COPC - chemical of potential concern

EPC - exposure point concentration

ND - chemical not detected in background samples

A -NJDEP 2011. Surface Water Quality Standards, Saline Water Chronic Values, January 2011, downloaded January 24, 2011

C -EPA 2006. EPA Region 3 Biological Technical Assistance Group Marine Screening Benchmarks,
Mid-Atlantic Risk Assessment: Ecological Risk Assessment, http://www.epa.gov/reg3hwmd/risk/eco/index.htm

*-dissolved criteria

a - freshwater value is used as directed by EPA

Table 2-6
Comparison of Chemicals Evaluated in the EPA/ERT's Ecological Risk Assessment of Area 1 to Background Concentrations
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	CAS No.	Sediment (mg/kg)		Dissolved Surface Water (µg/L)	
		EPC[1]	Background Concentration[2]	Maximum Concentration[1]	Background Concentration[2]
Antimony	7440-36-0	30.9	2.0	26.5	ND
Arsenic	7440-38-2	14.2	38.7	36.2	ND
Copper	7440-50-8	30	176	82.6 *	ND
Lead	7439-92-1	1098 *	181.5	1780 *	ND
Manganese	7439-96-5	70.2	185.1	NA	ND
Silver	7440-22-4	0.3	1.3	NA	ND
Zinc	7440-66-6	67	143.5	NA	ND

Notes:

1 - value consists of the 95% Upper Confidence Limit (UCL) of Area 1 sediment taken from EPA/ERT's ecological risk assessment of Area 1.

2 - background concentrations consist of the 95% Upper Prediction Limit (UPL) of sediment and dissolved surface water samples as calculated in the SLERA.

mg/kg - milligrams per kilogram

µg/L - micrograms per liter

EPC - exposure point concentration

NA - chemical not analyzed for

ND - not detected

* - chemical identified as a risk driver in EPA/ERT's Ecological Risk Assessment of Area 1 and retained as a chemical of potential concern in the Step 3a evaluation

Table 2-7
Food Chain Exposure Model Receptor Life History Input Parameters
Raritan Bay Slag Site
Old Bridge/Sayreville, New Jersey

Modeled Receptor	Body Weight (kg)	Food Ingestion Rate (kg/day)	Soil/Sediment Ingestion Rate (kg/day)	Site Foraging Factor
Belted Kingfisher [1,2,5]	0.147	0.0735	0.00242	1
Mink [1,2,5]	1.02	0.161	0.015	1
Short-tailed Shrew [1,2,5]	0.0168	0.0093	0.00048	1
American Robin [1,2,5,7]	0.081	0.098	0.01	0.67
Kestrel [1,2,5,8]	0.119	0.036	0.00036	0.083
Red Fox [1,2,5]	4.54	0.43	0.012	1
Northern Bobwhite [1,2,5]	0.174	0.014	0.0013	1
Eastern Cottontail [1,3,5]	1.22	0.237	0.015	1
Muskrat [1,2,5]	1.17	0.351	0.033	1
Osprey [1,2,6,9]	1.629	0.342	0.00342	0.50
Canada Goose [4]	3.29	0.1467	0.00128	1
Semipalmated Plover [4,10]	0.0498	0.01125	0.00231	0.58

Notes:

1 - Body weights consist of the average of mean adult values as reported in Wildlife Exposure Factors Handbook (EPA 1993).

2 - Food ingestion rates normalized to body weights were calculated based on the average of values (when more than one value was reported) as presented in Wildlife Exposure Factors Handbook (EPA 1993).

3 - Food ingestion rate not reported in EPA 1993. Value used as reported in Sample and Suter (1994).

4 - Body weights, food ingestion rates, and sediment ingestion rates taken from EPA/ERTs ecological risk assessment of Area 1 (EPA/ERT 2010).

5 - Soil/sediment ingestion rates calculated using values as presented in Beyer et al. (1994) and/or as reported in the screening level ecologcial risk assessment for the Raritan Bay Slag Site (CDM 2011).

6 - Sediment ingestion rate was not located. A sediment ingestion rate of one percent was assumed.

7 - site foraging factor seasonally adjusted based on life history of American robin migrating to and from New York as reported in Wildlife Exposure Factors Handbook (EPA 1993). Based on the information provided the American robin is estimated to reside at the site for eight months for a foraging factor of 0.67 (8 months divided by 12 months).

8 - site foraging factor calculated by dividing the estimated total area of Area 9 upland areas which is approximately 8.82 hectares by an average territory for American kestrel of 106 hectares as reported in Wildlife Exposures (EPA 1993).

9 - site foraging factor seasonally adjusted based on life history of the osprey as reported in Wildlife Exposure Factors Handbook (EPA 1993). Based on the information provided osprey are estimated to reside at the site for six months for a foraging factor of 0.5 (6 months divided by 12 months).

10 - site foraging factor seasonally adjusted based on life history of non-breeding semipalmated plover as reported by the Cornell Lab of Ornithology website (http://bna.birds.cornell.edu/bna/species/444/articles/). Based on the information provided the plover was estimated to reside at the site for seven months for a foraging factor of 0.58 (7 months divided by 12 months).

kg - kilograms

kg/day - kilograms per day

Table 2-8
95 Percent Upper Confidence Limits for Area 1 Sediment and Tissue Chemistry Results used in Food Chain Exposure Models
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical (mg/kg)	Sediment	Forage fish	Sea lettuce	Mollusks
Arsenic	14.2	3.7	13.6	7.90
Copper	30	5.9	12.7	19.1
Lead	1098	0.8	79.4	10.8
Silver	0.3	ND	ND	0.82
Zinc	67	93	50.5	84

Notes:
mg/kg - milligrams per kilogram
ND - not detected

Table 2-9
Avian Toxicity Reference Values
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Belted Kingfisher	American Robin	American Kestrel	Northern Bobwhite	Osprey	Canada Goose	Semipalmated Plover
	LOAEL	LOAEL	LOAEL	LOAEL	LOAEL	LOAEL	LOAEL
Arsenic	Not evaluated*	7.4 a	Not evaluated*	Not evaluated*	7.4 a	7.4 a	7.4 a
Cadmium	Not evaluated*	20 a	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Copper	61.7 a	61.7 a	Not evaluated*	Not evaluated*	61.7 a	61.7 a	61.7 a
Lead	11.3 a	11.3 a	11.3 a	11.3 a	11.3 a	11.3 a	11.3 a
Selenium	1 a	1 a	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Silver	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	60.5 j	60.5 j	60.5 j
Zinc	131 a	131 a	131 a	Not evaluated*	131 a	131 a	131 a
Hexavalent Chromium	Not evaluated*	26.6 l,h	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Benzo(b)fluoranthene	Not evaluated*	20 b,d	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Benzo(g,h,i)perylene	Not evaluated*	20 b,d	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Benzo(k)fluoranthene	Not evaluated*	20 b,d	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Chrysene	Not evaluated*	20 b,d	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Fluoranthene	Not evaluated*	20 b,d	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Pentachlorophenol	Not evaluated*	67.3 k,h	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Pyrene	Not evaluated*	20 b,d	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
alpha-Chlordane	Not evaluated*	10.7 a,e	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Aroclor-1254	Not evaluated*	1.8 a	1.8 a	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
4,4-DDD	Not evaluated*	0.028 a,g	0.028 a,g	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
4,4-DDE	Not evaluated*	0.028 a,g	0.028 a,g	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
4,4-DDT	Not evaluated*	0.028 a,g	0.028 a,g	0.028 a,g	Not evaluated*	Not evaluated*	Not evaluated*
Endosulfan II	Not evaluated*	100 a,h,i	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Endrin	Not evaluated*	0.1 a	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
gamma-Chlordane	Not evaluated*	10.7 a,e	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*
Methoxyclor	Not evaluated*	200 m,h	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*	Not evaluated*

Notes:

LOAEL - lowest-observed-adverse-effect level

TRV - toxicity reference value

a - TRVs taken from Sample, B.E., D.M. Opresko and G.W. Suter II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. ES/ER/TM-86/R3. Oak Ridge National Laboratoy, Oakridge, TN.

b - TRVs taken from Lockheed-Martin. 2002. Final Report, Atlantic Wood Industries, Ecological Risk Assessment, Portsmouth, Virginia. EPA Contract 68-C-99-223.

d - value for high molecular weight PAHs

e - value for chlordane

g - value for DDT and metabolites

h - no LOAEL located; value derived by multiplying the NOAEL by a factor of 10

i - value for endosulfan

j - TRVs taken from EPA. 2005. Ecological Soil Screening Levels (Eco-SSLs) for Silver. Washington, DC. US Environmental Protection Agency

k - TRVs taken from EPA. 2007. Eco-SSLs for Pentachlorophenol. Washington, DC. US Environmental Protection Agency

l - TRV for trivalent chromium from EPA. 2008. Eco-SSLs for Chromium. Washington, DC. US Environmental Protection Agency

m - Derived from LD50 for methoxychlor taken from Methoxychlor Reregistration Eligibility Decision (RED) June 30, 2004 EPA Publication No. EPA 738-R-04-010

* - Chemical not evaluated as no risks were noted in the screening level ecological risk assessment for modeled receptor species identified in column title.

Table 2-10
Mammalian Toxicity Reference Values
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Mink	Short-tailed Shrew	Red Fox	Eastern Cottontail	Muskrat
	LOAEL	LOAEL	LOAEL	LOAEL	LOAEL
Arsenic	0.524 a	1.498 a	0.36 a	0.501 a	0.524 a[1]
Copper	15.4 a	44 a	Not evaluated*	14.7 a	15.4 a[1]
Lead	61.53 a	175.83 a	42.25 a	58.79 a	61.53 a[1]
Selenium	0.254 a	0.725 a	0.174 a	Not evaluated*	0.254 a[1]
Silver	6.02 b	6.02 b	Not evaluated*	6.02 b	6.02 b
Benzo(b)fluoranthene	Not evaluated*	6.15 e,g,h	Not evaluated*	Not evaluated*	Not evaluated*
Benzo(g,h,i)perylene	Not evaluated*	6.15 e,g,h	Not evaluated*	Not evaluated*	Not evaluated*
Benzo(k)fluoranthene	Not evaluated*	6.15 e,g,h	Not evaluated*	Not evaluated*	Not evaluated*
Chrysene	Not evaluated*	6.15 e,g,h	Not evaluated*	Not evaluated*	Not evaluated*
Fluoranthene	Not evaluated*	6.15 e,g,h	Not evaluated*	Not evaluated*	Not evaluated*
Pentachlorophenol	Not evaluated*	5.275 a	Not evaluated*	Not evaluated*	Not evaluated*
Pyrene	Not evaluated*	6.15 e,g,h	Not evaluated*	Not evaluated*	Not evaluated*
alpha-Chlordane	Not evaluated*	10.9 a,i	Not evaluated*	Not evaluated*	Not evaluated*
Aroclor-1254	Not evaluated*	0.668 a	0.474 a	0.223 a	Not evaluated*
4,4-DDT	Not evaluated*	Not evaluated*	2.11 a,j	Not evaluated*	Not evaluated*
Endosulfan II	Not evaluated*	3.3 a,k,h	Not evaluated*	Not evaluated*	Not evaluated*
Endrin	Not evaluated*	1.094 a	Not evaluated*	Not evaluated*	Not evaluated*
gamma-Chlordane	Not evaluated*	10.9 a,i	Not evaluated*	Not evaluated*	Not evaluated*
Methoxyclor	Not evaluated*	17.6 a	Not evaluated*	Not evaluated*	Not evaluated*

Notes:

LOAEL - lowest-observed-adverse-effect level

TRV - toxicity reference value

1 - no TRV for muskrat located in Sample and Suter (1996); value for mink used

a - TRVs taken from Sample, B.E., D.M. Opresko and G.W. Suter II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. ES/ER/TM-86/R3. Oak Ridge National Laboratoy, Oakridge, TN.

b - TRVs taken from EPA. 2005. Ecological Soil Screening Levels (Eco-SSLs) for Silver. Washington, DC. US Environmental Protection Agency

e - TRVs taken from EPA. 2007. Eco-SSLs for Poly Aromatic Hydrocarbons (PAHs). Washington, DC. US Environmental Protection Agency

g - value for high molecular weight PAHs

h - no LOAEL located; value derived by multiplying the NOAEL by a factor of 10

i - value for chlordane

j - value for DDT and metabolites

k - value for endosulfan

* - Chemical not evaluated as no risks were noted in the screening level ecological risk assessment for modeled receptor species identified in column title.

Table 2-11
Biota-Sediment Accumulation Factors and Bioaccumulation Factors
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Fish Biota-Sediment Accumulation Factor		Earthworm Bioaccumulation Factor		Plant Bioaccumulation Factor		Small Mammal Bioaccumulation Factor	
Arsenic	0.26	p	0.11	b	0.036	b	0.06	c,m
Cadmium	Not applicable*		0.96	b	Not applicable*		Not applicable*	
Copper	0.20	p	0.04	b	0.4	b	Not applicable*	
Lead	0.001	p	0.03	b	0.045	b	17.1	c,m
Selenium	1.0	o	0.22	b	0.016	b	0.45	c,m
Silver	1.0	o	0.22	b	0.4	b	Not applicable*	
Zinc	1.4	p	0.56	b	Not applicable*		101	c,m
Hexavalent Chromium	Not applicable*		1.0	o	Not applicable*		Not applicable*	
Benzo(b)fluoranthene	Not applicable*		2.6	c	Not applicable*		Not applicable*	
Benzo(g,h,i)perylene	Not applicable*		2.94	c	Not applicable*		Not applicable*	
Benzo(k)fluoranthene	Not applicable*		2.60	c	Not applicable*		Not applicable*	
Chrysene	Not applicable*		2.29	c	Not applicable*		Not applicable*	
Fluoranthene	Not applicable*		3.04	c	Not applicable*		Not applicable*	
Pentachlorophenol	Not applicable*		1034	b	Not applicable*		Not applicable*	
Pyrene	Not applicable*		1.75	c	Not applicable*		Not applicable*	
alpha-Chlordane	Not applicable*		7,925.7	b,d	Not applicable*		Not applicable*	
Aroclor-1254	Not applicable*		1.13	b,e	0.01	b,e	1.0	o
4,4-DDD	Not applicable*		1.26	b,f	Not applicable*		4.9	c,l
4,4-DDE	Not applicable*		1.26	b,f	Not applicable*		4.9	c,l
4,4-DDT	Not applicable*		1.26	b,f	0.037	c	4.9	c
Endosulfan II	Not applicable*		97.9	b,d	Not applicable*		Not applicable*	
Endrin	Not applicable*		1,296.6	b,d	Not applicable*		Not applicable*	
gamma-Chlordane	Not applicable*		7,925.7	b,d	Not applicable*		Not applicable*	
Methoxyclor	Not applicable*		1,034	b,d	Not applicable*		Not applicable*	

Notes:

b - EPA Region 6 Multimedia Planning and Permitting Division, Office of Solid Waste., August 1999, Screening Level Ecological risk Assessment Protocol: Appendix C: Media to Receptor BCF Values

c - EPA, Guidance for Developing Ecological Soil Screening Levels, Attachment 4-1 Exposure Factors and Bioaccumulation

Models for Derivation of Wildlife Eco-SSLs, OSWER Directive 9285.7-55, Februray 2005.

d - BAF calculated using the regression equation: $LogBCF=(0.819*logK_{ow})-1.146$ as per Appendix C in source"b".

e - value for Aroclor 1254

f - value for 4,4'-DDE

l - value for DDT

m - no BAF values located; values shown are estimated tissue concentrations calculated using regression equation as presented in source "c"

o- default value of "1" used when no BSAF/BAF were located.

p - value calculated by dividing the 95% UCL concentratons of forage fish by 95% UCL sediment concentrations collected during EPA/ERT's investigation of Area 1 and presented in Table 2-8 as per the following:

arsenic BSAF of 0.26 = 3.7/14.2 lead BSAF of 0.001 = 0.8/1098

copper BSAF of 0.2 = 5.9/30 zinc BSAF of 1.4 = 93/67

* - no food chain exposure models were evaluated which required specific media to tissue bioaccumulation factor.

Table 4-1
Food Chain Exposure Model for the Belted Kingfisher
Raritan Bay Slag Superfund Site
Old Bridge/Sayerville, New Jersey

Chemical	Sediment			Fish			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Biota-Sediment Accumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Copper	42.5	0.00242	0.103	0.20	8.3	100%	0.0735	0.6	1	0.147	4.86	61.7	0.08
Lead	64.1	0.00242	0.155	0.001	0.05	100%	0.0735	0.0	1	0.147	1.08	11.3	0.10
Selenium	0.47	0.00242	0.001	1.0	0.47	100%	0.0735	0.03	1	0.147	0.244	1.00	0.24
Zinc	36.4	0.00242	0.088	1.40	51	100%	0.0735	3.7	1	0.147	26.09	131	0.20

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Sediment concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in sediment
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 140 mg/kg and moisture content was 54.2%.
ww = 140 x (1- 0.542)
ww = 64.1 mg/kg

Table 4-2
Food Chain Exposure Model for the Mink
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Sediment			Fish			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Biota-Sediment Accumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	6.6	0.015	0.099	0.26	1.74	100%	0.161	0.28	1	1.02	0.371	0.524	0.71
Copper	42.5	0.015	0.64	0.20	8.5	100%	0.161	1.4	1	1.02	1.97	15.4	0.13
Lead	64.1	0.015	0.96	0.001	0.06	100%	0.161	0.0	1	1.02	0.95	61.5	0.02
Selenium	0.47	0.015	0.007	1.0	0.47	100%	0.161	0.08	1	1.02	0.081	0.254	0.32
Silver	0.9	0.015	0.014	1.0	0.92	100%	0.161	0.15	1	1.02	0.159	6.02	0.03

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Sediment concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in sediment
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 140 mg/kg and moisture content was 54.2%.
ww = 140 x (1- 0.542)
ww = 64.1 mg/kg

Table 4-3
Food Chain Exposure Model for the Short-Tailed Shrew
Raritan Bay Slag Superfund Site
Old Bridge/Sayerville, New Jersey

Chemical	Soil			Invertebrates			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration	Ingestion Rate	Total Ingested Chemical	Bioaccumulation Factor	Concentration	Percent of Diet	Ingestion Rate	Total Ingested Chemical				Value	Hazard Quotient
	mg/kg w.w.	kg/day	mg/day		mg/kg w.w.		kg/day	mg/day		kg	mg/kg/day	mg/kg/day	
Arsenic	12.7	0.00048	0.006	0.11	1.4	100%	0.0093	0.013	1	0.0168	1.1	1.50	0.76
Copper	23.4	0.00048	0.011	0.04	0.9	100%	0.0093	0.009	1	0.0168	1.2	44	0.03
Lead	515	0.00048	0.2	0.03	15.5	100%	0.0093	0.14	1	0.0168	23	176	0.13
Selenium	0.37	0.00048	0.000	0.22	0.08	100%	0.0093	0.001	1	0.0168	0.06	0.725	0.08
Silver	0.77	0.00048	0.000	0.22	0.17	100%	0.0093	0.002	1	0.0168	0.12	6.02	0.02
Benzo(b)fluoranthene	0.14	0.00048	0.0001	2.6	0.36	100%	0.0093	0.003	1	0.0168	0.20	6.15	0.03
Benzo(g,h,i)perylene	0.08	0.00048	0.0000	2.94	0.23	100%	0.0093	0.002	1	0.0168	0.130	6.15	0.02
Benzo(k)fluoranthene	0.11	0.00048	0.0001	2.60	0.30	100%	0.0093	0.003	1	0.0168	0.167	6.15	0.03
Chrysene	0.11	0.00048	0.0001	2.29	0.25	100%	0.0093	0.0023	1	0.0168	0.140	6.15	0.02
Fluoranthene	0.13	0.00048	0.0001	3.04	0.39	100%	0.0093	0.004	1	0.0168	0.22	6.15	0.04
Pentachlorophenol	0.01	0.00048	0.000005	1,034	10.44	100%	0.0093	0.097	1	0.0168	5.78	5.28	**1.1**
Pyrene	0.16	0.00048	0.0001	1.75	0.28	100%	0.0093	0.0026	1	0.0168	0.16	6.15	0.03
Alpha-Chlordane	0.003	0.00048	0.000002	7,926	25.0	100%	0.0093	0.233	1	0.0168	13.8	10.9	**1.3**
Aroclor 1254	2.1	0.00048	0.001	1.13	2.4	100%	0.0093	0.023	1	0.0168	1.40	0.668	**2.1**
Endosulfan II	0.04	0.00048	0.00002	97.9	3.5	100%	0.0093	0.0325	1	0.0168	1.9	3.30	0.59
Endrin	0.003	0.00048	0.000001	1,297	3.27	100%	0.0093	0.030	1	0.0168	1.81	1.09	**1.7**
Gamma-Chlordane	0.01	0.00048	0.00001	7,926	91	100%	0.0093	0.85	1	0.0168	51	10.9	**4.6**
Methoxychlor	0.02	0.00048	0.000008	1,034	16.5	100%	0.0093	0.154	1	0.0168	9.1	17.6	0.52

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in soil
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 612 mg/kg and moisture content was 15.9%.
ww = 612 x (1- 0.159)
ww = 515 mg/kg

Table 4-4
Food Chain Exposure Model for the American Robin
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Soil			Invertebrates			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration	Ingestion Rate	Total Ingested Chemical	Bioaccumulation Factor	Concentration	Percent of Diet	Ingestion Rate	Total Ingested Chemical				Value	Hazard Quotient
	mg/kg w.w.	kg/day	mg/day		mg/kg w.w.		kg/day	mg/day		kg	mg/kg/day	mg/kg/day	
Arsenic	12.7	0.01	0.13	0.11	1.4	100%	0.098	0.14	0.67	0.081	2.2	7.4	0.29
Cadmium	0.15	0.01	0.001	0.96	0.14	100%	0.098	0.014	0.67	0.081	0.1	20.0	0.01
Copper	23.4	0.01	0.23	0.04	0.9	100%	0.098	0.09	0.67	0.081	2.7	61.7	0.04
Lead	515	0.01	5	0.03	15.5	100%	0.098	1.5	0.67	0.081	55.1	11.3	**4.9**
Selenium	0.37	0.01	0.004	0.22	0.08	100%	0.098	0.008	0.67	0.081	0.1	1.0	0.10
Zinc	36.2	0.01	0.36	0.56	20.3	100%	0.098	2.0	0.67	0.081	19.5	131	0.15
Hexavalent Chromium	0.58	0.01	0.006	1.0	0.58	100%	0.098	0.056	0.67	0.081	0.5	27	0.02
Benzo(b)fluoranthene	0.14	0.01	0.001	2.6	0.36	100%	0.098	0.035	0.67	0.081	0.3	20	0.02
Benzo(g,h,i)perylene	0.08	0.01	0.001	2.94	0.23	100%	0.098	0.023	0.67	0.081	0.2	20	0.01
Benzo(k)fluoranthene	0.11	0.01	0.001	2.60	0.30	100%	0.098	0.029	0.67	0.081	0.2	20	0.01
Chrysene	0.11	0.01	0.001	2.29	0.25	100%	0.098	0.024	0.67	0.081	0.2	20	0.01
Fluoranthene	0.13	0.01	0.001	3.04	0.39	100%	0.098	0.038	0.67	0.081	0.3	20	0.02
Pentachlorophenol	0.010	0.01	0.0001	1034	10	100%	0.098	1.02	0.67	0.081	8.5	67	0.13
Pyrene	0.16	0.01	0.002	1.75	0.3	100%	0.098	0.028	0.67	0.081	0.2	20	0.01
Alpha-Chlordane	0.003	0.01	0.00003	7,926	25.0	100%	0.098	2.45	0.67	0.081	20.3	11	**1.9**
Aroclor 1254	2.1	0.01	0.021	1.13	2.4	100%	0.098	0.24	0.67	0.081	2.1	1.8	**1.2**
4,4'-DDD	0.004	0.01	0.000	1.26	0.005	100%	0.098	0.000	0.67	0.081	0.004	0.028	0.15
4,4'-DDE	0.006	0.01	0.00006	1.26	0.008	100%	0.098	0.001	0.67	0.081	0.007	0.028	0.26
4,4'-DDT	0.12	0.01	0.001	1.26	0.15	100%	0.098	0.015	0.67	0.081	0.1	0.028	**4.6**
Endosulfan II	0.036	0.01	0.000	97.9	3.5	100%	0.098	0.34	0.67	0.081	2.8	100	0.03
Endrin	0.003	0.01	0.00003	1,297	3.27	100%	0.098	0.321	0.67	0.081	2.7	0.1	**26.5**
Gamma-Chlordane	0.012	0.01	0.000	7,926	91.4	100%	0.098	9	0.67	0.081	74.1	11	**6.9**
Methoxychlor	0.016	0.01	0.0002	1,034	16.5	100%	0.098	1.62	0.67	0.081	13.4	200	0.07

Notes:

LOAEL = lowest observed adverse effect level

kg = kilogram

kg/day = kilogram per day

mg/kg w.w. = milligram per kilograms wet weight

mg/kg/day = milligram per kilograms per day

Bold - indicates hazard quotient greater than threshold of one

Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.

wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)

where:

ww - wet weight concentration

Cs - dry weight concentration in soil

% moisture - percent moisture

For example, the 95% UCL dry weight concentration for lead was 612 mg/kg and moisture content was 15.9%.

ww = 612 x (1- 0.159)

ww = 515 mg/kg

Table 4-5
Food Chain Exposure Model for the American Kestrel
Raritan Bay Slag Superfund Site
Old Bridge/ Sayreville, New Jersey

Chemical	Soil			Small Mammals			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration	Ingestion Rate	Total Ingested Chemical	Bioaccumulation Factor	Concentration[1]	Percent of Diet	Ingestion Rate	Total Ingested Chemical				Value	Hazard Quotient
	mg/kg w.w.	kg/day	mg/day		mg/kg w.w.		kg/day	mg/day		kg	mg/kg/day	mg/kg/day	
Lead	515	0.00036	0.19	NA	17.1	100%	0.036	0.62	0.083	0.119	0.6	11.3	0.05
Zinc	36.2	0.00036	0.013	NA	101.0	100%	0.036	3.64	0.083	0.119	2.5	131	0.02
Aroclor 1254	2.1	0.00036	0.00077	1.0	2.1	100%	0.036	0.0773	0.083	0.119	0.1	1.8	0.03
4,4'-DDD	0.004	0.00036	0.000001	4.9	0.019	100%	0.036	0.001	0.083	0.119	0.000	0.028	0.02
4,4'-DDE	0.006	0.00036	0.000002	4.9	0.032	100%	0.036	0.001	0.083	0.119	0.001	0.028	0.03
4,4'-DDT	0.12	0.00036	0.0000	4.9	0.58	100%	0.036	0.021	0.083	0.119	0.014	0.028	0.52

Notes:

1 = No BAFs for soil to small mammals available for lead and zinc; concentrations in small mammals estimated using regression equations per Tables 4a and 4c in Attachment 4
1, Guidance for Developing Ecological Soil Screenng Levels (EPA 2005).

LOAEL = lowest observed adverse effect level

NA - no BAF required see note 1

kg = kilogram

kg/day = kilogram per day

mg/kg w.w. = milligram per kilograms wet weight

mg/kg/day = milligram per kilograms per day

Bold - indicates hazard quotient greater than threshold of one

Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.

wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)

where:

ww - wet weight concentration

Cs - dry weight concentration in soil

% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 612 mg/kg and moisture content was 15.9%

ww = 612 x (1- 0.159)

ww = 515 mg/kg

Table 4-6
Food Chain Exposure Model for the Red Fox
Raritan Bay Slag Superfund Site
Old Bridge/ Sayreville, New Jersey

Chemical	Soil			Small Mammals			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Bioaccumulation Factor	Concentration[1] mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	12.7	0.012	0.15	NA	0.06	100%	0.43	0.027	1	4.54	0.039	0.360	0.11
Lead	515	0.012	6.2	NA	17.1	100%	0.43	7.4	1	4.54	3.0	42.3	0.07
Selenium	0.37	0.012	0.004	NA	0.45	100%	0.43	0.194	1	4.54	0.044	0.174	0.25
Aroclor 1254	2.1	0.012	0.026	1.0	2.1	100%	0.43	0.923	1	4.54	0.2	0.474	0.44
4,4'-DDT	0.12	0.012	0.001	4.9	0.58	100%	0.43	0.25	1	4.54	0.055	2.11	0.03

Notes:

1 = No BAFs for soil to small mammals available for arsenic, lead and selenium; concentrations in small mammals estimated using regression equations per Tables 4a and 4c in Attachment 4-1, Guidance for Developing Ecological Soil Screenng Levels (EPA 2005).

LOAEL = lowest observed adverse effect level

NA - no BAF required see note 1

kg = kilogram

kg/day = kilogram per day

mg/kg w.w. = milligram per kilograms wet weight

mg/kg/day = milligram per kilograms per day

Bold - indicates hazard quotient greater than threshold of one

Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.

wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)

where:

ww - wet weight concentration

Cs - dry weight concentration in soil

% moisture - percent moisture

For example, the 95% UCL dry weight concentration for lead was 612 mg/kg and moisture content was 15.9%.
ww = 612 x (1- 0.159)

ww = 515 mg/kg

Table 4-7
Food Chain Exposure Model for the Northern Bobwhite
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemcial	Soil			Plants			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Bioaccumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Lead	515	0.0013	0.7	0.045	23	100%	0.014	0.32	1	0.174	6	11.3	0.51
4,4'-DDT	0.12	0.0013	0.000	0.037	0.004	100%	0.014	0.0001	1	0.174	0.001	0.028	0.04

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in soil
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 612 mg/kg and moisture content was 15.9%.
ww = 612 x (1- 0.159)
ww = 515 mg/kg

Table 4-8
Food Chain Exposure Model for the Eastern Cottontail
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Soil			Plants			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Bioaccumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	12.7	0.015	0.19	0.036	0.46	100%	0.237	0.11	1	1.22	0.24	0.501	0.49
Copper	23.4	0.015	0.4	0.4	9.4	100%	0.237	2.2	1	1.22	2.1	14.7	0.14
Lead	515	0.015	8	0.045	23	100%	0.237	5.5	1	1.22	11	58.8	0.18
Silver	0.77	0.015	0.012	0.4	0.31	100%	0.237	0.073	1	1.22	0.070	6.02	0.01
Aroclor 1254	2.1	0.015	0.032	0.01	0.021	100%	0.237	0.005	1	1.22	0.031	0.223	0.14

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in soil
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 612 mg/kg and moisture content was 15.9%.
ww = 612 x (1- 0.159)
ww = 515 mg/kg

Table 4-9
Food Chain Exporsure Model for the Muskrat
Raritan Bay Slag Superfund Site
Old Bridge.Sayreville, New Jersey

Chemcial	Sediment			Plants			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Bioaccumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	6.6	0.033	0.218	0.036	0.238	100%	0.351	0.083	1	1.17	0.257	0.524	0.49
Copper	42.5	0.033	1.4	0.4	17	100%	0.351	6.0	1	1.17	6.3	15.4	0.41
Lead	64.1	0.033	2.12	0.045	2.88	100%	0.351	1.01	1	1.17	2.67	61.5	0.04
Selenium	0.47	0.033	0.016	0.016	0.008	100%	0.351	0.003	1	1.17	0.016	0.254	0.06
Silver	0.92	0.033	0.030	0.4	0.37	100%	0.351	0.13	1	1.17	0.14	6.02	0.02

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Sediment concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in sediment
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for lead was 140 mg/kg and moisture content was 54.2%
ww = 140 x (1- 0.542)
ww = 64.1 mg/kg

Table 4-10
Food Chain Exposure Model for the Osprey
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Sediment			Fish		Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg d.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Concentration mg/kg d.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	14.2	0.00342	0.049	3.7	100%	0.342	1.28	0.5	1.629	0.41	7.4	0.06
Copper	30	0.00342	0.103	5.9	100%	0.342	2.0	0.5	1.629	0.65	61.7	0.01
Lead	1098	0.00342	3.755	0.8	100%	0.342	0.3	0.5	1.629	1.2	11.3	0.11
Silver[1]	0.3	0.00342	0.001	ND	100%	0.342	NA	0.5	1.629	0.0003	60.5	0.00001
Zinc	67	0.00342	0.229	93	100%	0.342	31.7	0.5	1.629	9.8	131	0.07

Notes:
LOAEL = lowest observed adverse effect level
NA = not applicable; chemical not detected in food item
ND - chemical not detected
kg = kilogram
kg/day = kilogram per day
mg/kg d.w. = milligram per kilograms dry weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Sediment and fish tissue concentrations consist of the 95% Upper Confidence Level (UCL) of Area 1 samples collected in support of EPA/ERTs ecological risk assessment of Area 1
1 = silver not detected in food item; total dose of silver consists only of that consumed via incidential ingestion of sediment

Table 4-11
Food Chain Exposure Model for the Canada Goose
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Sediment			Plants (*Ulva*)		Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg d.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Concentration mg/kg d.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	14.2	0.00128	0.02	13.6	100%	0.1467	1.99	1	3.29	0.61	7.4	0.08
Copper	30	0.00128	0.04	12.7	100%	0.1467	1.87	1	3.29	0.58	61.7	0.01
Lead	1098	0.00128	1.4	79.4	100%	0.1467	11.64	1	3.29	3.97	11.3	0.35
Silver[1]	0.3	0.00128	0.0004	ND	100%	0.1467	NA	1	3.29	0.0001	60.5	0.000002
Zinc	67	0.00128	0.09	50.5	100%	0.1467	7.4	1	3.29	2.28	131	0.02

Notes:
NOAEL = no observed adverse effect level
LOAEL = lowest observed adverse effect level
NA = not applicable; chemical not detected in food item
ND - chemical not detected
kg = kilogram
kg/day = kilogram per day
mg/kg d.w. = milligram per kilograms dry weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Sediment and plant tissue concentration consists of the 95% Upper Confidence Level (UCL) of Area 1 samples collected in support of EPA/ERTs ecological risk assessment of Area 1
1 = silver not detected in food item; total dose of silver consists only of that consumed via incidiential ingestion of sediment

Table 4-12
Food Chain Exposure Model for the Semipalmated Plover
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Chemical	Sediment			Mollusks		Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg d.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Concentration mg/kg d.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested Chemical mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Arsenic	14.2	0.00231	0.033	7.90	100%	0.01125	0.089	0.58	0.0498	1.4	7.4	0.19
Copper	30	0.00231	0.069	19.1	100%	0.01125	0.215	0.58	0.0498	3.3	61.7	0.05
Lead	1098	0.00231	2.536	10.8	100%	0.01125	0.122	0.58	0.0498	31.0	11.3	**2.7**
Silver	0.3	0.00231	0.001	0.82	100%	0.01125	0.009	0.58	0.0498	0.12	60.5	0.002
Zinc	67	0.00231	0.155	84	100%	0.01125	0.947	0.58	0.0498	12.8	131	0.10

Notes:
NOAEL = no observed adverse effect level
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg d.w. = milligram per kilograms dry weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Sediment and mollusk tissue concentrations consist of the 95% Upper Confidence Level (UCL) of Area 1 samples collected in support of EPA/ERTs ecological risk assessment of Area 1

Table 7-1
Preliminary Remediation Goal for Lead in Soil based on the American Robin Food Chain Model
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Food Chain Model Parameters[1]	Value	Unit	Chemical	Bioaccumulation Factor[2]	LOAEL TRV (mg/kg-day)	LOAEL-based PRG (mg/kg d.w.)
Hazard Quotient (HQ)	1	unitless	Lead	0.03	11.3	126
Soil Ingestion Rate (IR-S)	0.01	kg/day				
Food Ingestion Rate (IR-food)	0.098	kg/day				
Body Weight (BW)	0.081	kg				
Site Foraging Factor (SFF)	0.67					
Percent of Diet (%D)	100%					

Notes:

1 - Food chain model parameters and calculations are presented in Table 2-7

2 - BAF is literature-based as noted in Table 2-11.

d.w. - dry weight
kg/day - kilograms per day
LOAEL - lowest-observed-adverse-effect-level
mg/kg-day - milligrams per kilogram per day
PRG - preliminary remediation goal
TRV - toxicity reference value
PRGs calculated using the following equation:
PRG = ((HQ x BW x TRV)/(SFF x (IR-S + BAF x %D x IR-food)))/(1-Moisture)

Table 7-2
Preliminary Remediation Goal for Lead in Sediment based on the Semipalmated Plover Food Chain Model
Raritan Bay Slag Superfund Site
Old Bridge/Sayreville, New Jersey

Food Chain Model Parameters[1]	Value	Unit	Chemical	Bioaccumulation Factor[2]	LOAEL TRV (mg/kg-day)	LOAEL-based PRG (mg/kg d.w.)
Hazard Quotient (HQ)	1	unitless	Lead	0.010	11.3	401
Sediment Ingestion Rate (IR-S)	0.00231	kg/day				
Food Ingestion Rate (IR-food)	0.01125	kg/day				
Body Weight (BW)	0.0498	kg				
Site Foraging Factor (SFF)	0.58	percent				
Percent of Diet (%D)	100%	percent				

Notes:

1 - Food chain model parameters and calculations are presented in Table 2-7

2 - Bioaccumulation factor calcualted by dividing the 95% UCL of lead in Area 1 mollusks (10.8 mg/kg) by the 95% UCL of lead (1098 mg/kg) detected in Area 1 sediment.

d.w. - dry weight

kg/day - kilograms per day

LOAEL - lowest-observed-adverse-effect-level

mg/kg-day - milligrams per kilogram per day

PRG - preliminary remediation goal

TRV - toxicity reference value

PRGs calculated using the following equation:

PRG = (HQ x BW x TRV)/(SFF x (IR-S + BAF x %D x IR-food))

Table 8-1
Food Chain Exposure Models for the Short-tailed Shrew and American Robin Run Using a Modified Data Set
Raritan Bay Slag Superfund Site
Sayreville/Old Bridge, New Jersey

Short-tailed Shew

Chemical	Soil			Invertebrates			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Bioaccumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Pentachlorophenol	0.005	0.00048	0.000002	1,034	4.7	100%	0.0093	0.044	1	0.0168	2.62	5.28	0.5
Alpha-Chlordane	0.003	0.00048	0.000001	7,926	23.3	100%	0.0093	0.22	1	0.0168	12.9	10.9	**1.2**
Aroclor 1254	0.035	0.00048	0.00002	1.13	0.04	100%	0.0093	0.0004	1	0.0168	0.02	0.668	0.03
Gamma-Chlordane	0.003	0.00048	0.000001	7,926	19.8	100%	0.0093	0.18	1	0.0168	11	10.9	**1.0**

American Robin

Chemical	Soil			Invertebrates			Food		Site Foraging Factor	Body Weight	Dose	LOAEL	
	Concentration mg/kg w.w.	Ingestion Rate kg/day	Total Ingested Chemical mg/day	Bioaccumulation Factor	Concentration mg/kg w.w.	Percent of Diet	Ingestion Rate kg/day	Total Ingested mg/day		kg	mg/kg/day	Value mg/kg/day	Hazard Quotient
Alpha-Chlordane	0.003	0.01	0.00003	7,926	23.3	100%	0.098	2.3	0.67	0.081	18.9	11	**1.8**
Aroclor 1254	0.035	0.01	0.0004	1.13	0.04	100%	0.098	0.004	0.67	0.081	0.04	1.8	0.02
4,4'-DDT	0.011	0.01	0.0001	1.26	0.01	100%	0.098	0.001	0.67	0.081	0.01	0.028	0.4
Gamma-Chlordane	0.003	0.01	0.00003	7,926	19.8	100%	0.098	1.9	0.67	0.081	16.1	11	**1.5**

Notes:
LOAEL = lowest observed adverse effect level
kg = kilogram
kg/day = kilogram per day
mg/kg w.w. = milligram per kilograms wet weight
mg/kg/day = milligram per kilograms per day
Bold - indicates hazard quotient greater than threshold of one
Soil concentrations consist of the 95% Upper Confidence Level (UCL) of Area 9 samples evaluated in the screening level ecological risk assessment.
wet weight concentrations converted as follow: ww = Cs x (1 - % moisture)
where:
ww - wet weight concentration
Cs - dry weight concentration in soil
% moisture - percent moisture
For example, the 95% UCL dry weight concentration for Aroclor 1254 was 0.041 mg/kg and moisture content was 13.7%.
ww = 0.041 x (1- 0.137)
ww = 0.035 mg/kg

Exhibit 1

Tables 14 and 17 taken from the United States Environmental Protection Agency/Environmental Response Team report for the Raritan Bag Slag Superfund Site, Volume 2 of 2 Biological Assessment and Ecological Risk Assessment

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Table 14. Hazard Quotients for Sediment-Dwelling Organisms Based on 95% UCL Sediment Concentrations Using Low Effect and Medium Effect Benchmarks
Raritan Bay Slag Site
Middlesex County, NJ

	95% UCL Sediment Conc. mg/kg d.w.	NJ SW sed ERLs Low Effects Range mg/kg d.w.	HQ	NJ SW sed ERMs Medium Effects Range mg/kg d.w.	HQ
Antimony	30.9	nb	nb	nb	nb
Arsenic	14.2	8.2	**1.7**	70	0.2
Copper	30	34	0.9	270	0.1
Lead	1,098	47	**23.4**	218	**5.0**
Manganese	70.2	nb	nb	nb	nb
Silver	0.3	1	0.3	3.7	0.1
Zinc	67	150	0.4	410	0.2

NJ SW sed ERLs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999. Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Low (ERL).

NJ SW sed ERMs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999. Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Medium (ERM).

HQ- Hazard Quotient
mg/kg d.w. - milligrams per kilogram dry weight
nb - no benchmark available
95% UCL - 95 percent upper confidence level
Values in "bold" have HQs greater than 1.0

Table 17. Hazard Quotients (HQs) for Dissolved Metals in Surface Water Based on Acute and Chronic Benchmarks
Raritan Bay Slag Site
Middlesex County, NJ

	Maximum Surface Water Concentration	ecotox SW	EPA 2002 AWQC SW chronic BM	HQ	EPA 2002 AWQC SW acute BM	HQ
	ug/L	ug/L	ug/L		ug/L	
Antimony	26.5	nb	nb	nb	nb	nb
Arsenic	36.2	nb	36	**1.0**	69	0.5
Copper	82.6	2.4	3.1	**26.6**	4.8	**17.2**
Lead	1,780	8.1	8.1	**220**	210	**8.5**

EPA 2002 AWQC SW chronic BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
EPA 2002 AWQC SW acute BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
Ecotox SW - US EPA OSWER (Ofiice of Solid Waste and Emergency Response) 1996. Eco Update Ecotox Thresholds, Washington D.C. EPA 540/F-95/038
AWQC SW chronic BMs- Ambient Water Quality Criteria for Seawater - Chronic benchmark values
AWQC SW Acute BMs - Ambient Water Quality Criteria for Seawater - Acute benchmark values
HQ - Hazard Quotient
nb - no benchmark available
Values in "bold" have HQs greater than 1.0
ug/L - micrograms per liter
U - Undetected

Appendix A

United States Environmental Protection Agency/Environmental Response Team reports for the Raritan Bay Slag Superfund Site, Volume 1 of 2 (Chemistry Assessment Report) and Volume 2 of 2 (Biological Assessment and Ecological Risk Assessment)

Best Available Copies

REPORT 1 OF 2
RARITAN BAY SLAG SITE
OLD BRIDGE AND SAYREVILLE, MIDDLESEX COUNTY, NEW JERSEY

CHEMICAL ASSESSMENT REPORT

CHARACTERIZATION OF SLAG\WASTE MATERIAL
FATE AND TRANSPORT OF CONTAMINANTS
BIOMONITORING OF CONTAMINANTS
Amended April 2010

U.S. EPA Work Assignment No.: 0-356
Lockheed Martin Work Order No.: EAC00356
U.S. EPA Contract No.: EP-C-04-032

Prepared by:
Lockheed Martin/REAC

Prepared for:
EPA/ERT

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REAC Task Leader

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Dennis Miller Date
Program Manager

0356-DFR-060909

R2-0006809

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LIST OF ACRONYMS AND ABBREVIATIONS

Ag	Silver
As	Arsenic
AsCuS	Arsenic copper sulfide
CFR	Code of Federal Regulations
cm	centimeter
Cr	Chromium
Cu	Copper
CuO_2	Cuprite
g	gram
EPA	Environmental Protection Agency
ERT	Emergency Response Team
Fe	Iron
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectrometry
M	molar
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
Mn	Manganese
Ni	Nickel
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
oz	ounce
Pb	Lead
$PbCO_3$	Lead Carbonate
PbO	Lead Oxide
Pb(OH)Cl	Lead Hydroxide Chloride
Pb_2OSO_4	Lanarkite
PbS	Lead Sulfide
$PbSO_4$	Lead Sulfate
$PbZrO_3$	Lead Zirconium Oxide
RCRA	Resource Conservation and Recovery Act
REAC	Response, Engineering and Analytical Contract
Sb	Antimony
SiO_2	Silicate
SOP	Standard Operating Procedure
Sn	Tin
TAL	Target Analyte List
TCLP	Toxicity Characteristic Leaching Procedure
U	not detected
µg/L	microgram per liter
µm	micron
U.S.	United States
WA	work assignment
XRD	X-ray Diffraction
Zn	Zinc
%	percent
<	less than

EXECUTIVE SUMMARY

The Raritan Bay Slag site, located in Old Bridge and Sayreville, New Jersey (NJ), extends approximately 1.5 miles from Margaret's Creek Wetlands Area along the seawall adjacent to the Old Bridge Waterfront Park to the waterfront area just west of the Cheesequake Creek Inlet western jetty. In the late 1960s and early 1970s, lead-bearing slag and other demolition material were used as fill and stabilizing material for the construction of the seawall. In addition, slag and associated materials were used to build-up the western jetty at the Cheesequake Creek Inlet.

The objectives of this work assignment (WA) were to characterize the metallurgical waste material at the site; evaluate the potential for release and transport of contaminants associated with the waste material; collect data in support of human and ecological risk assessment; and conduct an initial ecological risk assessment. Final results are presented in two separate documents. This document presents the data collected and an assessment of the data relative to the chemical nature, fate and transport of the contaminants. A second document utilizes the same data in an initial ecological risk assessment (EPA/ERT/REAC 2009).

The results of this evaluation are as follows:

• Slag from the seawall, Cheesequake Creek Inlet western jetty and along the beachfront west of the jetty was highly heterogenous with a wide range of concentrations. Particularly high concentrations were found for arsenic (As), copper (Cu), lead (Pb), antimony (Sb), tin (Sn) and zinc (Zn). Lead concentrations exceeded 10,000 mg/kg for 15 of the 17 samples analyzed and exceeded 100,000 mg/kg for 5 of the 17 samples analyzed

• Metal speciation analysis of the slag reinforced the conclusion of heterogeneity of the material present, and confirmed that it was metallurgical waste material. The analyses identified various Pb, Cu, As and Sn compounds as dominant species. Five different Pb species were identified as dominant species in the slag. Of particular importance was the finding that interior and exterior layers of the slag contained different Pb species, with the interior layers containing Pb species with greater affinity to mobilize from the potential weathering and erosion of the slag. This finding is consistent with a conclusion that the slag is weathering.

• The leachability and/or mobility of the metals from the slag were evaluated under acidic conditions following Toxicity Characteristic Leaching Procedure (TCLP) methods. All 17 slag samples exceeded the Resource Conservation and Recovery Act (RCRA) regulatory limit for Pb of 5.0 mg/L based on TCLP, designating the slag as hazardous waste. Leachable metal determinations were also presented as concentration leached based on dry weight. Lead concentrations leached from the slag exceeded 1,000 mg/kg for 15 of the 17 slag samples, with 10 samples having leachable Pb concentrations exceeding 10,000 mg/kg.

• The leachability and/or mobility of the metals from the slag were also evaluated using neutral salt solutions. Particularly high levels of Pb were determined to be leachable and/or mobilized from neutral salt solutions with higher levels of leachable Pb in the interior (non-weathered) samples compared with the exterior layer of the slag boulders. This finding is consistent with a conclusion that contaminants within the slag are leachable and therefore able to be released into the environment under normal conditions at the site.

• Soil (*i.e.*, beach sediments) and pore water collected along the intertidal zone adjacent to the seawall had high metal concentrations consistent with the release of metals from the slag. Soils along the entire length of the intertidal zone adjacent to the seawall are characterized as having a high spatial variability, with a wide range of concentrations, particularly for Pb, Sb, As and Cu. Pore water was analyzed for dissolved metals and total metals. High concentrations of total Pb, manganese (Mn), As and Sb were measured in the unfiltered samples. In addition, high concentrations of dissolved Mn, Pb As, and Sb were measured for several of the filtered samples. The wide variation of contaminant concentrations in the soils and pore water is consistent with the influence of Site characteristics. The finding of elevated pore water metal concentrations is of particular importance as this supports a conclusion that Site contaminants are being released into the environment.

• Biomonitoring techniques were utilized to assessing contaminant release and transport. These techniques are particularly useful in locations with periodic or sporadic contaminant releases. Utilizing the principles of biomonitoring, biota sampling focused on the predominant organisms that were residing or utilizing the intertidal and subtidal zones at this site to determine which organisms would accumulate contaminants released from the seawall. The organisms collected from the intertidal zone included two mollusks (ribbed mussels [*Geukensia demissa*] and long neck or steamer clams [*Mya arenaria*]), macroalgae (*Ulva*), and foraging fish (killifish). In addition, hard shell clams (*Mercenaria mercenaria*) were collected in the subtidal zone. *Ulva* had the highest metal accumulations for Pb, Mn, As, chromium (Cr) and nickel (Ni). Of the three mollusks, juvenile *Mya* clams accumulated the highest concentrations of Pb and Cu. All three mollusks accumulated comparable concentrations of As and silver (Ag). The biomonitoring data are consistent with a conclusion that Site contaminants are being released into the environment and are being biologically accumulated. The biota data also support a conclusion that the contaminants are being transported away from the source material; this conclusion is supported by the accumulation of contaminants in biota not residing immediately adjacent to the slag material.

1.0 INTRODUCTION

The Raritan Bay Slag site (the Site), located in Old Bridge Township and the Borough of Sayreville, New Jersey (NJ), is approximately 1.5 miles in length and consists of the waterfront area between Margaret's Creek and the area just beyond the western jetty at the Cheesequake Creek Inlet. The Site consists of a sea wall that extends for approximately 2,500 feet along the Old Bridge Waterfront Park adjacent to Bayview Drive in Laurence Harbor, public beach areas, three jetties, the Cheesequake Creek Inlet western jetty that extends for about 800 feet from the mouth of the Cheesequake Creek into Raritan Bay and the waterfront area west of the jetty (Figure 1).

In September 1972, the New Jersey Department of Environmental Protection (NJDEP) was advised by a local environmental commission member that lead-bearing waste material was being deposited along the Laurence Harbor beachfront. The material was reported to be non-recoverable, low-yield metallic waste from a blast furnace and blast furnace rubble. The slag was deposited at the beachfront in the late 1960s and early 1970s, mostly in the form of blast furnace pot bottoms, in an area that had sustained significant beach erosion and damage due to a series of storms in the 1960s. Demolition debris in the form of concrete and a variety of bricks, including fire bricks, was also placed along the beachfront. A portion of the seawall also contains large riprap believed to have been placed over the slag when the grassed and paved portion of the park was developed.

The western jetty at Cheesequake Creek Inlet has been in existence since the United States (U.S.) Army Corps of Engineers constructed it in the late nineteenth century. The slag was reportedly placed on the jetty during the same general time period as the construction of the seawall. The entire jetty is covered with slag that is similar in appearance to that which is present on the seawall. The waste material and slag was used to supplement the jetty and was used as a fill and stabilizing material for the seawall. Metal contaminants associated with the slag and associated waste material include antimony (Sb), arsenic (As), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), zinc (Zn), and tin (Sn).

Under this work assignment (WA), the U.S. Environmental Protection Agency (EPA)/Emergency Response Team (ERT) requested Response Engineering and Analytical Contract (REAC) personnel to perform both chemical and biological assessments that are presented as separate reports. The biological assessment evaluates the risk/impact of the metals being released from the slag on the biological communities associated with the intertidal zone adjacent to the sea wall (EPA/ERT/REAC 2009). The objectives of this chemical assessment report include:

- Characterization of the metal contaminants associated with the slag and waste material used for the construction of the sea wall and Cheesequake Creek Inlet Western Jetty;
- Evaluation of the leachability and mobility of metals from the slag and associated waste material;
- Assessment of contaminant release through biomonitoring techniques;
- Evaluation of the fate and transport of the metals in environmental media including soils (*i.e.*, beach sediments), pore water and biota of the intertidal zone adjacent to the sea wall;
- Collection of data relevant to human health and ecological risk assessments.

2.0 SITE SETTING AND DESCRIPTION

The Site is bordered to the south, east, and west by residential properties and State Highway 35, and to the north by Raritan Bay. The Site extends for approximately 1.5 miles and includes the Old Bridge Waterfront Park, public beaches, three jetties, the Cheesequake Creek Inlet western jetty and the waterfront area west of the jetty (Figures 1, 2 and 3). The Old Bridge Waterfront Park, consisting of walking paths, gazebo and public parking area, is protected by a seawall, which is constructed with layers of slag and fill. Slag and fragments of slag are scattered along the entire length of the beach area between the seawall and cordgrass (*Spartina alterniflora*) beds (Figure 4). Figure 5 depicts the slag at the top of the seawall during high tide. Figures 6 and 7 depict the Cheesequake Creek Inlet western jetty at high tide when the water has risen to close to the top of the jetty and Figures 8 and 9 depict an assortment of slag used for constructing the jetty. Figure 10 shows the waterfront area just west of the jetty with slag and fragments of slag scattered along the waterfront.

Intertidal Zone Along Seawall

The intertidal zone adjacent to the seawall (Figures 1 and 2) consists of an open stretch of beach with slag and slag debris that extends for 20 to 30 feet before reaching the *Spartina* beds. Figure 4 depicts the area along the seawall within the intertidal zone at low tide with the *Spartina* beds situated adjacent to the seawall. The *Spartina* beds (Figure 11) extend for 10 to 15 feet within the mid to high tide range of the intertidal zone along the entire length of the seawall. The intertidal zone immediately beyond the *Spartina* beds primarily consists of open sand beach, cobble stones to medium sized rocks and randomly scattered slag. The green macroalgae (*Ulva* sp) was attached to the bottom substrate or to the cobble stones or rocks within this area that extended from the mid tidal level to beyond the low tidal level. It was noted that the *Ulva* did not colonize or attach to the slag that was scattered in this area. The *Ulva* was prominent but was not growing profusely within this intertidal zone.

Invertebrates that were prevalent in the intertidal zone either within or in proximity of the *Spartina* beds were limited to two species of mollusks: ribbed mussel (*Geukensia demissa*) (Figure 12) and long neck or steamer clam (*Mya arenaria*) (Figure 13). A dense colony of ribbed mussels was situated within the *Spartina* beds buried just below the surface of the sediments with a portion of the bivalve shell slightly extending above the surface of the sediments, allowing for the siphon to be extended into the water column for filtering. Most of the *Mya* clams were completely buried in the sediments from just below the surface to depths of six to eight inches. The hard shell clam (*Mercenaria mercenaria*) was found inhabiting the subtidal zone just beyond the intertidal zone. The hard shell clams were buried in the sediment at just below the surface. The biological assessment report for this WA provides an evaluation of the exposure of the organisms to metals associated with the slag boulders in this intertidal zone (EPA/ERT/REAC 2009).

3.0 SAMPLING DESIGN AND METHODS

The sampling design focused upon two primary objectives. One objective was to collect a representative assortment of waste rock/slag samples to characterize the metals associated with and leaching from the slag. Slag samples were collected along the sea wall, along the Cheesquake Creek Inlet western jetty and along the waterfront area west of the jetty. The slag samples were analyzed for total metals and for identification of the dominant metal species. In addition, the mobility and/or leaching potential of the metals associated with the slag were assessed based on Toxicity Characteristic Leaching Procedure (TCLP) methods and use of neutral salt solution to simulate seawater. This evaluation also included a characterization of exterior and interior slag samples.

The second objective of the sampling design was to document the release of contaminants from source areas and assess the fate and transport of the metals leaching from the slag and associated waste material. This second objective was met by a biomonitoring approach, utilizing both chemical analyses of abiotic media (soil and pore water) and evaluation of the contaminant uptake by the biota inhabiting or utilizing the intertidal and subtidal zones along the seawall. The criteria for the selection of target biomonitoring species were taken from Boening 1999; Butler 1971; Phillips 1977; and Phillips 1978, and are as follows:

- The organisms can integrate exposure over time;
- The organisms feeding strategy and/or other behavior characteristics establish an exposure pathway consistent with environmental chemistry of the contaminant of interest;
- The organism can concentrate contaminants and, therefore allow the evaluation of contaminants that are present in the environment at or below the analytical detection limit;
- The organism accumulates the pollutant without being adversely affected, if possible;
- The organism is an important foraging food source for higher level biota;
- The organism is sedentary (sessile) in order to be representative of the area of collection;
- The organism is abundant in the study area;
- The organism is sufficiently long lived to allow the sampling of more than one year class, if possible;
- The organism is of reasonable size to provide adequate tissue for analyses and accurate weight measurement; and
- The organism is easy to collect/sample and hardy enough to survive in the laboratory, allowing depuration (clearing) before chemical analyses.

The organisms chosen for the biomonitoring sampling were selected in an attempt to meet as many of the above criteria as possible given the species that are actually present at the Raritan Bay Slag Site. One of the primary considerations was the ability to bioaccumulate metals being released from the slag. In addition, there was consideration as to whether animals and plants at the site could potentially be consumed by human or ecological receptors (to increase the utility of the data generated). Based on the field reconnaissance of the sampling area and the organism selection criteria above, several target species were identified for sampling, including mollusks (ribbed mussels, long neck clam and hard shell clam), polychaetes, macroalge (*Ulva*) and foraging fish (killifish).

Mollusks or bivalves are known to be effective biomonitors of metal contaminants meeting many of the criteria for an ideal biomonitoring organism; however, no one particular species is universally suitable. When possible and practical it is advisable to initiate a biomonitoring assessment using several species representing different exposure pathways (Boening 1999). The three prominent bivalves (ribbed mussel, long neck clam and hard shell clam) at this Site represent different feeding and/or habitat characteristics.

Ulva species have demonstrated their capability as biomonitors of metal contamination including Cu, Pb, Mn, Ni and Zn (Besada *etal*. 2009, Villares *etal*. 2005, 2001, 2002, Ho 1990). Both the laminar structure of this macroalgae, providing a high surface area to volume ratio, and its capacity to grow in contaminated areas increases its potential as a useful biomonitor.

Killifish (*Fundulus* sp.) were the predominant foraging fish utilizing the intertidal zone at the Site. In addition, killifish are known to have a limited seasonal home range (Lotrich 1975). The killifish continuously move in and out of this intertidal zone with the tide and could potentially be exposed to the metals associated with the slag via surface water and foraging.

Polychaetes, residing within the interstitial sediments of this intertidal zone, would be in direct contact with the sediments and pore water that could be contaminated with metals associated with the slag. However, the population density of the polycheate community within this intertidal zone was too small for effective sampling during the site investigation. Local residents were observed collecting worms to be used for bait along the beach area just east of the sea wall. Numerous worms were easily collected by the local residents with the use of a trowel, with the largest worms ranging in size up to several inches in length. No evidence of these same type of worms were found along the seawall.

Soil and pore water sampling was co-located with the biota sampling, particularly for the ribbed mussels and Mya clams, to integrate exposure from the environmental media at the same locations.

The site investigation activities occurred over four sampling days on September 10, 11, 19 and 22, 2008. Sampling and analytical methods are provided in the following sections.

3.1 Slag Sampling and Analytical Methods

Sampling of the slag was performed by identifying and selecting individual pieces of slag along the seawall, the Cheesequake Creek Inlet western jetty and at the waterfront area west of the jetty. A total of 17 pieces of slag was collected by chiseling off fragments from the slag using a cole chisel and hammer.

Appendix C provides the photographs of the slag and samples. Figures C-1 to C-8 show the five slag samples originating from the seawall, identified as samples SW-1 through SW-5. Figures C-9 to C-20 show the 10 slag originating from the jetty from which samples were chiseled. These samples are designated as Jetty 1, 2A, 2B, 3A, 3B, 4, 5, 6, 7A and 7B. Figures C-21 and C-22 show the slag along the waterfront just west of the jetty from which samples were collected, designated as West Jetty 1 and 2.

Six slag samples from the jetty were collected by chiseling off just the exterior crust from the slag (Jetty 2A, 3A and 7A) and then chiseling off an interior sample below the crust (Jetty 2B, 3B and 7B). All of the remaining slag samples are whole samples that consist of exterior and interior layers of the slag.

All slag samples were pulverized and homogenized to a powder in the laboratory using a puck mill. The pulverized slag samples were analyzed for total metal concentrations of As, Cu, Pb, Sb, Sn and Zn by Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) following acid digestion. X-ray diffraction (XRD) was used for metal speciation determinations. In addition, the potential leachability or mobility of the metals from the 17 slag samples was evaluated based on exposure to acidic conditions as defined by the Toxicity Characteristic Leaching Procedure (TCLP) and by exposure to a neutral (weak) salt solution (0.01 molar [M] calcium chloride solution). Appendix A provides the analytical report and the standard operating procedures (SOPs).

Ten soil samples (*i.e.*, beach sediments) collected by Weston Solutions, Inc. adjacent to slag were analyzed for total metals by ICP-AES and for metal speciation by XRD. Five samples were collected along the intertidal zone adjacent to the seawall and five samples were collected along or near the Cheesequake Creek Inlet western jetty (Weston Solutions 2009).

3.2 Soil Sampling and Analytical Methods

A total of 11 co-located soil (*i.e.*, beach sediment) samples were collected at the ribbed mussel and *Mya* clam collection points (Figure 2). The soil samples were collected after the ribbed mussels and *Mya* clams were collected to avoid disturbing the biota. Soil samples were collected with a trowel and placed into 8-ounce (oz) glass jars. Samples were shipped to the subcontract laboratory and were analyzed for target analyte list (TAL) metals and Sn.

3.3 Pore Water Sampling and Analytical Methods

Pore water samples were collected by inserting a glass pipette into the soil at a depth of 1.5 to 2 inches below the surface. The end of the pipette that was inserted into the soil was covered with nylon screen to prevent the entrainment of soil. The pore water was siphoned through the pipette using a portable peristaltic pump. Individual decontaminated pipettes and tubing were used for collecting each sample. Five pore water samples were collected. Each of the samples was collected within proximity of the *Mya* clam collection points (Figure 2). The pore water was collected when the tide water had receded to avoid collection of surface water. One half of each sample volume was filtered by passing the water through a 0.45 micron (µm) filter and preserved to a pH of less than (<) 2.0 standard units with nitric acid. The other half of each sample was not filtered and preserved to pH < 2.0. Pore water samples were shipped to the subcontract laboratory and were analyzed for TAL metals and Sn as total metals and filtered dissolved metals.

3.4 Killifish (*Fundulus* sp.) Sampling and Analytical Methods

Five composite samples of killifish each consisting of eight individual fish were collected along the seawall during mid-tide using a seine net. Figure 2 presents the sampling area where the seining occurred. The killifish were placed into 2.5-gallon pails containing aerated seawater and transported back to the ERT/REAC Biological Laboratory for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into glass jars and frozen. Samples were shipped to the subcontract laboratory, homogenized and analyzed for target analyte list (TAL) metals, Sn and percent (%) solids.

3.5 Ribbed Mussel (*Geukensia demissa*) Sampling and Analytical Methods

Ribbed mussels were collected at six areas along the seawall at mid-tide. Figure 2 presents the six sampling locations designated as RM-1 to RM-6. The ribbed mussels were found to be prevalent amongst the *Spartina* (marsh grass) beds that are approximately 40 to 60 feet from the seawall. The ribbed mussels, most of which were seen projecting from the sediment, were collected by hand and ranged in size from 3.8 to 8.0 centimeters (cm). Eight to twelve ribbed mussels were collected at each sampling location to produce six composite samples, placed into large glass jars containing Rartian

Bay water, aerated and brought back to the ERT/REAC Biological Laboratory for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into a 16 ounce (oz). glass jar and frozen. The tissue was removed from each bivalve shell while frozen and the composite sample of the tissue was weighed. Tissue samples were shipped frozen to the subcontract laboratory, homogenized and analyzed for TAL metals, Sn and % solids.

3.6 Long Neck Clam (*Mya arenaria*) Sampling and Analytical Methods

Mya clams were collected at five areas along the seawall at mid-tide within or near the *Spartina* beds. Figure 2 presents the five sampling locations (*Mya* 1 to *Mya* 5). The *Mya* clams were either observed partially buried in the sediment and collected by hand or were collected using a clam rake. The clams ranged in size from 1 to 4 cm with the number of individual clams in each composite sample ranging from 5 clams for *Mya*-3 to 106 clams for *Mya*-2. The clams were transported back to the ERT/REAC Biological Laboratory alive, placed into large glass flasks with Raritan Bay water and aerated for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into a 16 oz. glass jar and frozen. The tissue from each clam was removed while frozen and the composite sample of tissue was weighed. Samples were shipped frozen to the subcontract laboratory, homogenized and analyzed for TAL metals, Sn and % solids.

3.7 Hard Shell Clam (*Mercenaria mercenaria*) Sampling and Analytical Methods

Mercenaria were collected using a clam rake at a water depth of 3.5 to 4 feet at mid-level tide just offshore of the sea wall. Figure 2 presents the approximate area from which the clams were collected. After numerous hauls with the clam rake, a total of 10 clams were collected at three different size ranges (2.0 inches, 2.5 inches and 3.5 inches). The clams were subdivided into three composite samples based on the three size ranges. The clams were transported back to the ERT/REAC Biological Laboratory alive, placed into large glass flasks with Raritan Bay water and aerated for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into a glass jar and frozen. The tissue from each clam was removed while frozen and the composite sample of the tissue was weighed. Tissue samples were shipped frozen to the subcontract laboratory, homogenized and analyzed for TAL metals, Sn and % solids.

3.8 Polychaete Sampling

Sampling for polychaete worms was performed by collecting sediment at the low to mid-tide level with a clam rake, transferring the sediment onto a sieve and washing the sediment through the sieve to separate the polychaetes from the sediment. Collections were attempted at depths from just below the surface to a depth of approximately 10 inches. However, only a few small polychaetes (<1 to 2 inches in size) were collected after sieving numerous sediment samples. This amounted to no more than 2.1 grams (g) wet weight, providing an insufficient volume of biomass to meet the data quality objectives

3.9 Sea Lettuce (*Ulva*) Sampling and Analytical Methods

Ulva was prevalent attached to bottom substrate (mostly attached to large stones and rocks) just beyond the *Spartina* beds at the mid-tide level. It was noted that attached *Ulva* was missing or sparse on the waste rock that was lying in these areas. Figure 2 presents the five sampling locations where the *Ulva* was collected and composited. Each of the composite samples was collected by hand, placed into a ziplock bag and brought back to the ERT/REAC Biological Laboratory. The *Ulva* was transferred to a sieve to be washed with distilled water, then blotted dry, transferred to sampling jars and frozen. Samples were shipped to the subcontract laboratory, homogenized and analyzed for TAL metals, Sn and % solids.

4.0 ANALYTICAL RESULTS

Appendix A provides the analytical report for the characterization of the slag. Section 4.1 provides an overview of the results. Appendix B provides the analytical report for the soil, pore water and biota. Sections 4.1 to 4.6 summarize the results.

4.1 Characterization of Slag and Soil Samples

A total of 17 slag samples were collected from the seawall, Cheesequake Creek Inlet western jetty and the waterfront area west of the jetty. Appendix C provides the photographs of the slag samples and Section 3.1 describes the samples collected.

Each of these 17 slag samples was analyzed for total elemental concentration for the primary metals of interest (As, Cu, Pb, Sb, Sn and Zn) along with the identification of the dominant mineral or chemical species using XRD procedures. In addition, two leachability tests assessing the mobility of the metals from the slag were performed. One test, TCLP, evaluated leachability under acidic conditions. The other test evaluated the leachability of metals from the slag when exposed to a neutral salt solution. Appendix A provides the analytical report. A summary of the results are provided below.

Ten soil samples collected by Weston Solutions, Inc. were also analyzed for total metal concentrations along with the identification of the dominant mineral or chemical species. Five of these samples were collected along the seawall within the intertidal zone and five samples were collected along or near the Cheesequake Creek Inlet western jetty (Weston Solutions 2009).

<u>Total Metal Concentrations</u>

The slag samples are characterized as highly heterogenous with a wide variation in elevated metal concentrations among the samples (Table 1a). Arsenic ranged from 8 mg/kg for Jetty 1 to 15,200 mg/kg for West Jetty-1. One particularly high concentration (445,000 mg/kg or 44.5%) of Cu was found in sample SW-2. Copper concentrations ranged from 101 mg/kg (Jetty 1) to 18,200 mg/kg (SW-3) for the remaining slag samples. With the exception of two samples (SW-2 and Jetty-1), the slag samples had Pb concentrations greater than 10,000 mg/kg, ranging from 12,900 mg/kg for West Jetty-2 to 131,000 mg/kg for Jetty-5. Antimony concentrations ranged from 31 mg/kg for Jetty-1 to 71,300 mg/kg for SW-1 and Sn ranged from 25 mg/kg for SW-2 to 11,400 mg/kg for Jetty-7A. Zinc concentrations ranged from 49 mg/kg for SW-2 to 13,400 mg/kg for SW-3 (Table 1a).

Table 2a presents the results for the ten soil samples collected adjacent to slag. Three of the five soil samples along the seawall had Pb concentrations above 1,000 mg/kg, ranging from 1,130 mg/kg to 2,580 mg/kg. The highest Pb concentrations (maximum concentration of 173,000 mg/kg) were from samples collected along or near the Cheesequake Creek Inlet western jetty. Additionally, the five soil samples collected along or near the Cheesequake Creek Inlet western jetty had elevated concentrations of As, Cu, Pb, Sb, Sn and Zn that exceeded 1,000 mg/kg (Table 2a).

Compound Speciation of Metals (XRD Analyses)

The XRD analyses performed on the slag and soil samples identified the crystal form of the dominant compound or species based on an initial phase identification.

Table 1b presents the dominant species identified for the slag samples. In many of the slag samples, there is a strong correlation between the total metal concentrations (Table 1a) and the dominant compounds identified by XRD (Table 1b). Iron (Fe) species and silicate (SiO_2) species were identified as dominant species for most of the samples and also various Pb, Cu, As and Sn species were also identified as dominant species. The dominant Pb species identified for a number of the slag samples included elemental Pb, lead carbonate ($PbCO_3$), lead zirconium oxide ($PbZrO_3$), lead sulfate ($PbSO_4$), and lead oxide (PbO). Different Pb species were identified in exterior versus interior layers of three slag boulders (*i.e.*, samples Jetty 2A, 2B, 3A, 3B, 7A and 7B). The interior samples contained lead carbonate ($PbCO_3$) as the dominant species, whereas the dominant species identified for the exterior samples included elemental Pb and $PbZrO_3$.

In Sample SW-2 (Cu concentration of 445,000 mg/kg) cuprite (Cu_2O) was the dominant species. Sample West Jetty 1 (As concentration of 15,200 mg/kg) contained arsenic copper sulfide (AsCuS) as a dominant species (Tables 1a and 1b)

Table 2b presents the dominant species identified for the soil samples. The four samples collected near the Cheesequake Creek Inlet western jetty with the highest Pb concentrations (*i.e.*, samples 48, 50, 51 and 52 collected by Weston Solutions, Inc.) contained several Pb species including $PbCO_3$, lead sulfide (PbS), lead hydroxide chloride (Pb(OH)Cl), lanarkite (Pb_2OSO_4), laurionite (PbOHCl) and lead sulfate ($PbSO_4$).

Toxicity Characteristic Leaching Procedure (TCLP)

The TCLP procedure was employed to determine the mobility of the metal contaminants from the slag under acidic conditions. The primary objective of the TCLP analysis is to simulate landfill conditions to assess if, over time, water or other liquids will react with the waste material or slag to mobilize contaminants and thus pose public health or environmental risk. The TCLP results are reported as the concentration in the aqueous phase as milligrams per liter (mg/L) (Table 3a) and as total elemental solids leaching from the slag as mg/kg dry weight (Table 3b).

Regulatory limits established under the Resource Conservation and Recovery Act (RCRA) (under Code of Federal Regulations [CFR] 40 CFR 261.24) are defined for both As and Pb as 5.0 mg/L. All of the 17 slag samples far exceed the 5.0 mg/L level for Pb with leachable Pb levels ranging from 17 mg/L to 3,140 mg/L (Table 3a). RCRA does not establish regulatory limits for the other metals analyzed. Arsenic levels in the leachate did not exceed the regulatory limit.

The TCLP analyses demonstrated that each of the 17 waste rock/slag samples leached Pb at concentrations ranging from 349 mg/kg to 62,700 mg/kg. Only two of the waste rock samples (SW-2 and Jetty-1) had concentrations of leachable Pb below 1,000 mg/kg; five waste rock samples exceeded 1,000 mg/kg and the remaining 10 samples exceeded 10,000 mg/kg (Table 3b). Slag sample SW-2 which contained the highest Cu concentration (445,000 mg/kg) had a leachable Cu concentration of 16,900 mg/kg (Table 3a). The slag samples did not leach appreciable quantities of the other metals with the exception of sample SW-5 which leached 1,005 mg/kg of Zn.

Leachability of Metals from Neutral Salt Exposure

Neutral salt extraction procedure was used to simulate the potential leachability and/or mobility of the metal contaminants from the slag from exposure to seawater.

Lead was determined to be leachable under these conditions (Table 3c). It was also demonstrated that the interior slag samples (samples Jetty 2B, 3B and 7B) had considerably higher levels of leachable Pb when compared with the leachable Pb levels from the exterior slag samples (samples Jetty 2A, 3A, and 7A). The exterior samples, essentially the outer crust of the slag, yielded leachable Pb levels of 8.3 mg/kg, 1.3 mg/kg and 10.1 mg/kg for samples Jetty 2A, 3A, and 7A, respectively. In comparison, the interior samples, that have not been previously exposed to Raritan Bay water, leached Pb at significantly higher levels (610 mg/kg, 870 mg/kg and 70.9 mg/kg for samples Jetty 2B, 3B and 7B, respectively) (Table 3c). As discussed above, the XRD characterization demonstrated differences in Pb species between the interior and exterior samples. The dominant Pb species for two of the three interior samples was identified as $PbCO_3$, which would have a greater affinity for leaching than the dominant Pb species for the exterior samples (elemental Pb and $PbZrO_3$).

Two other slag samples (samples Jetty 5 and Jetty 6) that are composite samples containing both interior and exterior layers also had high levels of leachable Pb with concentrations of 505 mg/kg and 72.2 mg/kg, respectively. Arsenic, Cu, Sb and Sn did not leach under the neutral salt water extraction. Zinc was leachable for a few of the slag samples with the highest leachable Zn level (126 mg/kg) for the Jetty-5 slag sample.

4.2 Pore Water Results

Five pore water samples were collected in the intertidal zone within proximity of the collection sites for the *Mya* (long neck shell) clams. Table 4 summarizes the results (as ug/L) for both the total metals in unfiltered and filtered samples.

Lead levels in the filtered and unfiltered pore water samples differed. Two particularly high Pb values (1,500 ug/L and 2,400 ug/L) were determined for the unfiltered pore water samples. Correspondingly, dissolved Pb values ranged from < 2.0 ug/L to a maximum value of 170 ug/L. The maximum Sb concentrations in the two unfiltered pore water samples were 56 ug/L and 270 ug/L and the maximum dissolved Sb concentrations were 19 ug/L and 130 ug/L, respectively. Dissolved As levels ranged from 11 ug/L to 86 ug/L and total As levels ranged from 19 ug/L to 230 ug/L.

Total and dissolved Mn levels were quite similar, ranging from 530 ug/L to 2,300 ug/L, indicating that Mn in the pore water was essentially available as dissolved metal. Copper and Zn concentrations were mostly below detection limits for both the total and dissolved metals.

A comparison of the metal concentrations in the surface water collected along the intertidal zone adjacent to the seawall by Weston Solutions, Inc (Weston Solutions 2009) during the same time period as this study reveals that certain metals were more concentrated in the pore water than surface water. For example, Mn levels in the surface water ranged between 100 ug/L to 200 ug/L and As ranged between < 10 ug/L to 11 ug/L as dissolved metal. Dissolved Pb levels in the pore water were comparable to the surface water levels along the seawall, ranging from 11.9 ug/L to 152 ug/L (Figure 5 in Weston Solutions 2009).

4.3 Soil Results

Eleven soil (*i.e.,* beach sediment) samples were collected within proximity of the collection sites for the ribbed mussels and the *Mya* clams (Table 4). In addition, 18 soil samples were collected along the seawall during the same time period as this study (September 2008) by Weston Solutions, Inc. (2009) (Table 5). The sampling locations of these 18 samples are shown in Figure 3.

The metal concentrations (Tables 4 and 5) in the soil samples along the seawall were highly heterogenous, analogous to what would be expected within a contaminated landfill site. Lead levels particularly stand out with concentrations ranging from 12 mg/kg to 5,860 mg/kg (Tables 4 and 5).

4.4 Mollusk Bioaccumulation Results

Five composite samples of the long neck clams (*Mya*), six composite samples of the ribbed mussels and three composite samples of the hard shell clams were analyzed for metals. Analyses were only performed on the soft tissue. The bivalve shells of the mollusks were discarded. Only juvenile *Mya* clams, less than one year old, were collected from the intertidal zone along the seawall. No adult *Mya* clams were found. Both the ribbed mussel and the hard shell clam composite samples were composed entirely of adult clams that were greater than two to four years old.

Tissue concentrations of Pb and Cu were highest in the juvenile *Mya* clams compared with either the adult ribbed mussels or the adult hard shell clams (Table 4). Lead levels for the *Mya* clams ranged from 3.4 mg/kg to 17 mg/kg (mean of 13.1 mg/kg) whereas ribbed mussels had Pb levels ranging from 3.0 mg/kg to 8.6 mg/kg (mean of 5.0 mg/kg) and the hard shell clam had Pb ranging from 1.7 mg/kg to 3.1 mg/kg (mean of 2.6 mg/kg). Copper levels for the *Mya* clams ranged from 8.5 mg/kg to 31 mg/kg (mean of 21.3 mg/kg) whereas Cu levels in ribbed mussels ranged from 10.4 mg/kg to 16 mg/kg (mean of 13.5 mg/kg) and the Cu levels in the hard shell clams ranged from 11 mg/kg to 14.3 mg/g (mean of 13.1 mg/kg).

Manganese levels were significantly higher in the *Mya* clams (4.3 mg/kg to 130 mg/kg) compared with the ribbed mussels (4.4 mg/kg to 7.1 mg/kg), but were lower than Mn levels in the hard shell clams (52 mg/kg to 200 mg/kg). Arsenic and Ag levels were comparable among all three mollusks with levels ranging from 1.4 mg/kg to 9.8 mg/kg for As and 0.15 mg/kg to 2.1 mg/kg for Ag. Zinc levels were higher in the *Mya* clams and hard shell clams than the ribbed mussels, but within the same range for the hard shell clams (Table 4).

4.5 *Ulva* Bioaccumulation Results

Five composite samples of *Ulva* collected within the intertidal zone were analyzed for metal concentrations. The *Ulva* bioconcentrated As, Cr, Pb, Mn and Ni at higher levels than the other biota (Table 4). Lead, Mn and Ni concentrations in the *Ulva* are of particular note with concentrations of 24 mg/kg to 80 mg/kg for Pb, 120 mg/kg to 280 mg/kg for Mn and 2.6 mg/kg to 4.7 mg/kg for Ni. Arsenic concentrations in the *Ulva* ranged from 4.7 mg/kg to 15 mg/kg and Cr ranged from 2.6 mg/kg to 5.0 mg/kg.

4.6 Foraging Fish (*Fundulus* sp.) Bioaccumulation Results

Five composite samples of killifish (*Fundulus* sp.) were analyzed for metals. Killifish exposure to the metal contaminants within the intertidal zone would primarily be the result of surface water exposure and foraging as the fish move in and out of the area with the tide. Data was collected for only one sampling area. Arsenic, Cu, Cr, Pb and Ni tissue concentrations in the killifish tissue were lower than measured for the other biota (Table 4).

5.0 SUMMARY AND CONCLUSIONS

The objectives of the chemical assessment are:

- Characterization of the metal contaminants associated with the slag and waste material used for the construction of the sea wall and Cheesequake Creek Inlet western jetty;
- Evaluation of the leachability and mobility of metals from the slag and associated waste material under acidic and simulated salt water conditions;
- Assessment of contaminant release through biomonitoring techniques;
- Evaluation of the fate and transport of the metals to environmental media including the soil, pore water and biota of the intertidal zone adjacent to the seawall;
- Collection of data relevant to human health and ecological risk assessments.

The slag originating from the seawall, the Cheesequake Creek Inlet western jetty and the waterfront area west of the jetty was characterized as being quite heterogeneous with a wide range of metal concentrations. Particularly high concentrations were measured for As, Cu, Pb, Sb, Sn and Zn (Table 1a). Lead concentrations exceeded 10,000 mg/kg for 15 of the 17 samples analyzed and exceeded 100,000 mg/kg for 5 of the 17 samples analyzed. Arsenic exceeded 1,000 mg/kg for 13 of the 17 samples analyzed with two of those samples exceeding 10,000 mg/kg. Copper exceeded 1,000 mg/kg for 14 of the 17 slag samples with five samples exceeding 10,000 mg/kg. The highest Cu concentration in the slag was determined at 445,000 mg/kg. Antimony exceeded 1,000 mg/kg for 12 of the 17 slag samples with seven samples exceeding 10,000 mg/kg. Tin exceeded 1,000 mg/kg for 14 of the 17 samples and Zn exceeded 1,000 mg/kg for 13 of the 17 samples (Table 1a). The total metal concentrations found within the slag material support a conclusion that the slag material present, at the Site, constitutes a contaminant source to the surrounding environment.

Compound speciation of the metals associated with the slag identified various Pb, Cu, As and Sn compounds as dominant species (Table 1b). Five different Pb species were identified as dominant species in the slag. Differences in Pb species between exterior and interior slag samples were identified. Analysis of the interior samples, slag that had not been previously exposed to weathering, identified lead carbonate ($PbCO_3$) as the dominant species for two of the three samples. The dominant species identified for the exterior samples were elemental Pb and $PbZrO_3$.

The results of the speciation investigation of the slag material are consistent with a conclusion that the slag is weathering, which would release contamination from the source material.

Leachability and/or mobility of the metal contaminants from the slag were evaluated based on acidic (TCLP) procedures and neutral salt solution extraction. The TCLP protocol provides an assessment of metals potentially being released under exposure to acidic groundwater and/or rainwater conditions, and evaluates the acceptability of the slag for landfill disposal. The TCLP results are given as metal concentrations leached in mg/L to compare results with regulatory limits defined by RCRA and as metals leached in mg/kg dry weight. All 17 slag samples exceeded the 5.0 mg/L RCRA regulatory limit for Pb, with leachable Pb levels ranging from 17 mg/L to 3,140 mg/L. None of the samples exceeded the As regulatory level (Table 3a). The results of the TCLP procedures demonstrate that the slag material fails TCLP and is therefore a hazardous waste.

The TCLP analysis determined that all 17 slag samples leached and/or mobilized Pb at concentrations ranging from 349 mg/kg to 62,700 mg/kg (Table 3b). Leachable Pb exceeded 1,000 mg/kg for 15 of the 17 samples with 10 samples having leachable Pb concentrations exceeding 10,000 mg/kg. The TCLP evaluation also determined that Cu had leached at a concentration of 16,900 mg/kg for the slag that contained the maximum Cu concentration (445,000 mg/kg).

A simulation of the leachability of metals from the slag was also evaluated by exposing the slag to neutral salt solutions. Lead was determined to be leachable and/or mobile from the neutral salt solution exposures with higher levels of leachable Pb determined for the interior (non-weathered) samples compared with the exterior (outer crust) of the slag (Table 3c). The exterior samples had leachable Pb values ranging from 8.3 mg/kg to 10.1 mg/kg, compared to the interior samples with leachable Pb values ranging from 70.9 mg/kg to 870 mg/kg. Weathering of the slag would result in exposing the interior layers of the slag containing more soluble lead species like lead carbonate ($PbCO_3$). The results of the neutral salt extraction tests demonstrated that contaminants can be released from the slag material under environmental conditions which exist at the Site. In addition the results of these tests are consistent with a conclusion that there is continued weathering of the slag and contaminant release to the surrounding environment.

Soils (*i.e.,* beach sediments) along the entire length of the intertidal zone adjacent to the seawall were characterized by a wide range of concentrations, particularly for Pb, Sb, As and Cu. The wide variations of concentrations are not unexpected since wave action mixes sediments along the shoreline and the physical characteristics of the shoreline create microenvironments. The highest concentrations were 5,860 mg/kg for Pb, 232 mg/kg for Sb, 29 mg/kg for As and 248 mg/kg for Cu (Tables 4 and 5). These results are consistent with a physical and chemical release (weathering) of contaminants from the slag material.

Pore water was analyzed for dissolved metals and total metals. High concentrations of total and dissolved Pb, Mn, As and Sb were measured for the unfiltered and filtered samples (Table 4). The results of the pore water analyses are consistent with a conclusion of release of contaminants from the slag material.

Biomonitoring focused on those organisms residing or utilizing the intertidal zone at this Site that would best assess contaminant release from the seawall. The predominant organisms collected from the intertidal zone included two mollusks (ribbed mussels and juvenile *Mya* clams), the macroalgae (*Ulva*), and the foraging fish (killifish). One mollusk, the hard shell clam, collected within the subtidal zone just beyond the intertidal zone, was also evaluated for its potential to accumulate metals associated with the Site. In addition, the site investigation revealed that certain organisms that were expected to be present, such as the polychaetes, were essentially absent along the intertidal zone of the seawall. Adult *Mya* clams also were absent during the site investigation along the seawall. The risk to the intertidal fauna and flora at this Site is evaluated in the separate biological assessment report for this project (EPA/ERT/REAC 2009).

Ulva, the sea lettuce, demonstrated the greatest bioaccumulation of metals, particularly for Mn, Pb, As, Cr and Ni (Table 4). Lead had accumulated up to 80 mg/kg in the *Ulva*. The bioaccumulation of metals by Ulva would be predominately from exposure to metals in the surface water. The elevated Pb concentrations in the surface water collected from the intertidal zone (See Weston Solutions, Inc 2009) are consistent with the elevated levels of Pb found in the *Ulva*. In addition, the contaminants found with the *Ulva* are consistent with a conclusion of release of contaminants from the slag material.

The juvenile *Mya* clams (less than one year old) had the highest Pb and Cu accumulations compared with the adult ribbed mussels and the adult hard shell clams. Arsenic and Ag were accumulated at comparable concentrations among the three mollusks. Manganese and Zn levels were at the highest levels in the hard shell clam (Table 4). The contaminants found within the bivalves collected at the Site are consistent with a conclusion of release of contaminants from the slag material.

The overall conclusions drawn from the data presented in this report are that the slag and associated debris used for constructing the seawall and building up of the Cheesequake Creek Inlet western jetty provide a significant source of metals to the environment including As, Cu, Pb, Sb, Sn and Zn. Lead is the predominant metal being released. The speciation chemistry performed in conjunction with the leachability testing clearly show that metals, particularly Pb, are in forms that can be released into the environment under conditions which can exist at the Site. The actual release of metals at the site is supported by the findings of metals within the pore water, surface water and soil at the site and is also supported by the bioaccumulation of the Site-related metals by biota residing at the Site.

6.0 LITERATURE CITED

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Tables 1a and 1b: Total Metal Concentrations and Compound Speciation of Slag Samples
Raritan Bay Slag Site
Old Bridge Township, NJ

Table 1a: Total Metal Concentrations of Slag Samples

		356-0001	356-0002	356-0003	356-0004	356-0005	356-0062	356-0063	356-0064	366-0065	356-0066	356-0067	356-0068	356-0069	356-0070	356-0071	356-0072	356-0073
Sample ID		SW-1	SW-2	SW-3	SW-4	SW-5	Jetty 1	Jetty 2A	Jetty 2B	Jetty 3A	Jetty 3B	Jetty 4	Jetty 5	Jetty 6	Jetty 7A	Jetty 7B	W. Jetty 1	W. Jetty 2
Sample Type		Whole	Whole	Whole	Whole	Whole	Whole	Exterior	Interior	Exterior	Interior	Whole	Whole	Whole	Exterior	Interior	Whole	Whole
Arsenic (As)	mg/kg	9,900	21	2,760	8,390	1,520	8	3,830	4,680	11,340	8,680	91	1,990	6,570	1,630	1,620	15,200	800
Copper (Cu)	mg/kg	20,000	445,000	18,200	9,720	3,370	101	3,200	3,010	10,640	11,600	510	5,190	3,270	8,720	8,360	8,570	250
Lead (Pb)	mg/kg	71,000	675	52,600	79,900	39,600	889	120,000	85,200	82,900	73,300	17,400	131,000	56,000	111,000	116,000	125,000	12,900
Antimony (Sb	mg/kg	71,300	36	2,950	26,700	2,150	31	46,800	45,200	33,800	34,400	630	6,680	38,200	640	500	5,170	1,320
Tin (Sn)	mg/kg	4,600	25	4,540	9,030	1,830	31	9,580	8,600	7,900	7,730	9,600	7,490	3,000	11,400	10,770	6,640	346
Zinc (Zn)	mg/kg	683	49	13,500	2,750	8,730	1,060	970	1,080	2,570	2,720	9,630	4,520	2,020	9,790	9,650	4,710	385

Table 1b: Dominant Compound Species of Slag Samples Determined by X-ray Diffraction (XRD)

	356-0001	356-0002	356-0003	356-0004	356-0005	356-0062	356-0063	356-0064	366-0065	356-0066	356-0067	356-0068	356-0069	356-0070	356-0071	356-0072	356-0073
Sample ID	SW-1	SW-2	SW-3	SW-4	SW-5	Jetty 1	Jetty 2A	Jetty 2B	Jetty 3A	Jetty 3B	Jetty 4	Jetty 5	Jetty 6	Jetty 7A	Jetty 7B	W. Jetty 1	W. Jetty 2
Sample Type	Whole	Whole	Whole	Whole	Whole	Whole	Exterior	Interior	Exterior	Interior	Whole	Whole	Whole	Exterior	Interior	Whole	Whole
Chemical Formula and Phase ID	FeS - Iron Sulfide	Cu_2O-Cuprite	Fe0.985S- Iron Sulfide	FeS- Troilite 2H	FeS- Troilite 2H	SiO_2- Quartz	FeS- Troilite 2H	Ba_2InSbO_6- Ba Sb Indium Oxi	FeS- Iron Sulfide	FeS- Iron Sulfide	Fayalite Magnesian Manganoa	$Pb(SO_4)$- Lead Sulfate	$PbSO_4$- Anglesite	Fe0.985S- Iron Sulfide	Fe0.985S- Iron Sulfide	Fe0.985S- Iron Sulfide	SiO_2- Quartz
	FeS - Trolite-2H	SiO_2- Quartz low	FeS- Troilite 2H	SiO_2- Quartz	FeS- Iron Sulfide	SiO_2- Tridymite	Pb- Lead	FeS- Iron Sulfide	FeS- Troilite 2H	FeS- Troilite 2H	Iron Silicon Oxide	SiO_2- Quartz	$PbSO_4$- Anglesite	FeS- Iron Sulfide	FeS- Iron Sulfide	FeS- Iron Sulfide	FeO(OH)- Geothite
	Cobalt-Nickel-Tin	SiO_2- Cristobalite	FeO- Iron Oxide	FeS- Iron Sulfide	Fe.9712O- Wuestite	$Al_6Si_2O_{13}$- Mullite	Co_3Sn_2- Cobalt Tin	FeS- Troilite 2H	$PbZrO_3$- Lead Zirconium Oxide	FeOOH- Iron Hydroxide Oxide	YBO_3- Yttrium Borate	$PbSO_4$- Anglesite	PbO- Litharge	FeS- Troilite 2H	$PbCO_3$- Cerussite	FeS- Troilite 2H	
	$CuCO_3$ - Copper Carbonate		Si- Silicon	Fayalite manganoan	FeO- Iron Oxide	Fe_2O_3- Hematite		Iron Cobalt Sulfide	$KMg_3(Si_3Al)O_{10}(OH)_2$- Phlogopite	Co_3Sn_2- Cobalt Tin	FeS- Iron Sulfide	Chromite	Fe_3O_4- Magnetite	Mg Zirconium Titanium Oxi	Titanomagnetite	ZnS- Zinc Sulfide	
	$FeSb_2$ - Seinajokite			Ni_2Y- Nickel Yttrium	Si- Silicon	Iron Tin Oxide		$PbCO_3$- Cerussite	SiO_2- Silicon Oxide	$ZnSO_4$- Zinkosite	Zn- Zinc	FeS- Iron Sulfide	$NaKZrSi_3O_9(H_2O)_2$- Georgecha	SiO_2- Quartz	ZnS- Zinc Sulfide	AsCuS- Arsenic Copper Sulfide	
					CuCl- Nantokite	Iron Hydroxide Oxide								Magnetite		$KMg_3(Si_3Al)O_{10}(OH)_2$- Phlogopite	
						Bytownite								Pb- Lead			

mg/kg - milligrams per kilogram
SW - Sea wall
W. Jetty - Westside of Jetty

Tables 2a and 2b: Total Metal Concentrations and Compound Speciation of Soil Samples
Raritan Bay Slag Site
Old Bridge Townnship, NJ

Table 2a: Total Metal Concentrations of Soil Samples

Sample ID		356-0006	356-0007	356-0008	356-0009	356-0010	356-0048	356-0049	356-0050	356-0051	356-0052
Arsenic (As)	mg/kg	86	43	36	3	9	1,022	122	943	1,980	3,060
Copper (Cu)	mg/kg	123	65	86	5	27	2,050	171	1,290	3,740	6,970
Lead (Pb)	mg/kg	2,580	1,130	2,120	36	96	60,200	2,690	77,200	173,000	147,000
Antimony (Sb	mg/kg	250	115	92	<5.0	10	3,440	176	4,500	17,600	9,900
Tin (Sn)	mg/kg	113	71	51	4	9	2,020	99	1,340	5,900	5,400
Zinc (Zn)	mg/kg	137	85	65	9	30	2,160	186	1,290	2,300	4,800

Table 2b: Dominant Compound Species of Soil Samples Determined by X-ray Diffraction (XRD)

Sample ID	356-0006	356-0007	356-0008	356-0009	356-0010	356-0048	356-0049	356-0050	356-0051	356-0052
Chemical Formula and Phase ID	SiO_2- Quartz low	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz	SiO_2- Quartz
	$CaTiO(SiO_4)$- Titanite	$KAlSi_3O_8$- Microcline			Muscovite 2M1	Muscovite 2M2	$KAlSi_3O_8$- Microline	$PbCO_3$- Cerussite	Strontium Calcium Sulfide	$PbCO_3$- Cerussite
						$PbCO_3$- Cerussite	Microline, maximum	ZrO_2- Zirconium Oxide	PbS- Galena	$Pb(SO_4)$- Anglesite
								Barium Manganese Silico	Sodium Nickel Chromium Molybdenum Oxid	$Ag(NO_3)(Ag_6O_8)$- Silver Nitrate Oxide
									Pb_2OSO_4- Lanarkite	$CaMgSi_2O_6$- Diopside
									$PbCO_3$- Cerussite	FeS-Iron Sulfide
									AlLiSi- Aluminum Lithium Silicon	FeS-Iron Sulfide
									Pb(OH)Cl- Lead Hydroxide Chloride	$Pb(SO_4)$- Lead Sulfate
									PbOHCl- Laurionite	$ZrSiO_4$- Zircon

mg/kg - milligrams per kilogram
Samples 0006 to 0010 Collected along seawall by Weston Solutions, Inc.
Samples 0048 to 0052 collected from beach adjacent to drawbridge by Weston Solutions, Inc.

Tables 3a, 3b and 3c: Leaching Assays using TCLP and Neutral Salt Procedures with Slag Boulders
Raritan Bay Slag Site
Old Bridge Township, NJ

Table 3a: TCLP Assay Results Based on Metals Leached (as mg/L) from Slag Samples

		356-0001	356-0002	356-0003	356-0004	356-0005	356-0062	356-0063	356-0064	356-0065	356-0066	356-0067	356-0068	356-0069	356-0070	356-0071	356-0072	356-0073
Sample ID		SW-1	SW-2	SW-3	SW-4	SW-5	Jetty 1	Jetty 2A	Jetty 2B	Jetty 3A	Jetty 3B	Jetty 4	Jetty 5	Jetty 6	Jetty 7A	Jetty 7B	W. Jetty 1	W. Jetty 2
Sample Type		Whole	Whole	Whole	Whole	Whole	Whole	Exterior	Interior	Exterior	Interior	Whole	Whole	Whole	Exterior	Interior	Whole	Whole
Arsenic (As)	mg/L	0.6	<0.02	0.10	3.6	0.08	<0.02	0.047	0.07	<0.02	0.15	0.17	0.08	0.18	<0.02	<0.02	<0.02	<0.02
Copper (Cu)	mg/L	<0.02	845	0.13	<0.02	<0.02	0.16	<0.02	<0.02	<0.02	0.25	<0.02	<0.02	0.06	<0.02	<0.02	<0.02	0.037
Lead (Pb)	mg/L	143	17	1,170	1,440	702	23	1,340	1,220	586	1,060	137	319	131	3,090	1,970	3,140	103
Antimony (Sb)	mg/L	0.7	0.17	0.07	0.6	0.09	0.16	0.6	0.45	0.06	0.42	0.9	0.6	10.1	<0.02	<0.02	0.05	<0.02
Tin (Sn)	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc (Zn)	mg/L	0.6	0.9	12	2.9	50	0.24	0.7	2.8	1.6	2.0	10	6	2.2	19	14	2.1	0.35

Table 3b: TCLP Assay Results Based on Metals Leached (as mg/kg dry weight) from Slag Samples

		356-0001	356-0002	356-0003	356-0004	356-0005	356-0062	356-0063	356-0064	356-0065	356-0066	356-0067	356-0068	356-0069	356-0070	356-0071	356-0072	356-0073
Sample ID		SW-1	SW-2	SW-3	SW-4	SW-5	Jetty 1	Jetty 2A	Jetty 2B	Jetty 3A	Jetty 3B	Jetty 4	Jetty 5	Jetty 6	Jetty 7A	Jetty 7B	W. Jetty 1	W. Jetty 2
Sample Type		Whole	Whole	Whole	Whole	Whole	Whole	Exterior	Interior	Exterior	Interior	Whole	Whole	Whole	Exterior	Interior	Whole	Whole
Arsenic (As)	mg/kg	11.6	<0.4	1.9	72.8	1.6	<0.4	0.9	1.5	<0.4	2.9	3.4	1.7	3.7	<0.4	<0.4	<0.4	<0.4
Copper (Cu)	mg/kg	<0.4	16,900	2.5	<0.4	<0.4	3.1	<0.4	<0.4	<0.4	4.9	<0.4	<0.4	1.1	<0.4	<0.4	<0.4	0.7
Lead (Pb)	mg/kg	2,860	349	23,300	28,750	14,000	464	26,800	24,400	11,700	21,190	2,740	6,380	2,610	61,800	39,500	62,700	2,050
Antimony (Sb)	mg/kg	15.0	3.5	1.4	11.4	1.8	3.1	12.7	9.0	1.2	8.5	17.8	11.1	10.1	<0.4	<0.4	0.9	<0.4
Tin (Sn)	mg/kg	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Zinc (Zn)	mg/kg	13	17	241	59	1,005	5	14	56	32	40	209	115	44	385	273	41	7

Table 3c: Neutral Salt Assay Results Based on Metals Leached (as mg/kg dry weight) from Slag Samples

		356-0001	356-0002	356-0003	356-0004	356-0005	356-0062	356-0063	356-0064	356-0065	356-0066	356-0067	356-0068	356-0069	356-0070	356-0071	356-0072	356-0073
Sample ID		SW-1	SW-2	SW-3	SW-4	SW-5	Jetty 1	Jetty 2A	Jetty 2B	Jetty 3A	Jetty 3B	Jetty 4	Jetty 5	Jetty 6	Jetty 7A	Jetty 7B	W. Jetty 1	W. Jetty 2
Sample Type		Whole	Whole	Whole	Whole	Whole	Whole	Exterior	Interior	Exterior	Interior	Whole	Whole	Whole	Exterior	Interior	Whole	Whole
As	mg/kg	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	1.0	<0.1	<0.1	<0.1	<0.1
Cu	mg/kg	0.3	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pb	mg/kg	0.2	<0.1	45.0	491	8.1	0.2	8.3	610	1.3	870	10.9	505	72.2	10.1	70.9	2.7	47.5
Sb	mg/kg	11.7	0.1	<0.1	0.161	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	0.3	0.4	1.0	<0.1	<0.1	<0.1	<0.1
Sn	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zn	mg/kg	<0.1	<0.1	9.6	8.1	2.8	<0.1	<0.1	2.13	<0.1	5.8	9.1	126	64.5	<0.1	23.5	<0.1	1.2

SW - Sea wall
W. Jetty - Westside of Jetty
mg/kg - milligrams per kilogram
mg/L - milligrams per Liter
TCLP - Toxicity Characteristic Leaching Procedure

Table 4. Analytical Results of Biota, Soil* and Pore Water Samples Collected Adjacent to Seawall
Raritan Bay Slag Site
Old Bridge Townnship, NJ

Sample Description	Sample Location	Units	Antimony (Sb)		Arsenic (As)		Copper (Cu)		Chromium (Cr)		Lead (Pb)		Manganese (Mn)		Nickel (Ni)		Silver (Ag)		Tin (Sn)		Zinc (Zn)	
			Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier
Pore Water	PW-A1 (Total/Unfiltered)	ug/L	4	U	20	U	80	U	12	U	8	U	840		9.6		4	U	400	U	40	U
	PW-B1 (Total/Unfiltered)	ug/L	2	U	19		40	U	7.6		10		540		6.9		2	U	200	U	20	U
	PW-C1 (Total/Unfiltered)	ug/L	56		71		40	U	9.8		1500		1800		10		2	U	200	U	27	
	PW-D1 (Total/Unfiltered)	ug/L	270		230		91		17		2400		1100		33		2	U	200	U	150	
	PW-E1 (Total/Unfiltered)	ug/L	9.7		39		40	U	7.9		160		2300		5.8		2	U	200	U	20	U
	PW-A2 (Filtered)	ug/L	2	U	11		40	U	6		4	U	840		7.3		2	U	200	U	20	U
	PW-B2 (Filtered)	ug/L	2	U	23		20	U	6.6		2	U	530		4.9		2	U	200	U	20	U
	PW-C2 (Filtered)	ug/L	19		41		20	U	6.6		2	U	1800		6.1		2	U	200	U	20	U
	PW-D2 (Filtered)	ug/L	130		86		40	U	7.1		170		1100		11		2	U	200	U	20	U
	PW-E2 (Filtered)	ug/L	4		29		20	U	6.4		2	U	2300		5.5		2	U	200	U	20	U
Soil* Samples	SS-RM1	mg/kg	0.22		5.6	J	4.4	J+	9		12		22	J	1.6	J+	0.11	U	11	UJ	25	
	SS-RM2	mg/kg	0.31		6.1	J	9.9	J+	9.5		16		44	J	3		0.095	U	9.5	UJ	31	
	SS-RM3	mg/kg	0.49		8.5	J	15		21		19		48	J	2.6		0.089	U	8.9	UJ	33	
	SS-RM4	mg/kg	1.5		6.9	J	11		7.7		94		28	J	2.3	J+	0.08		8	J	40	
	SS-RM5	mg/kg	6.1		13	J	22		18		660		260	J	5.8		0.19		18	J	57	
	SS-RM6	mg/kg	1.6		29	J	17		46		93		99	J	8.5		0.12		9.9	UJ	91	
	SS-MM1	mg/kg	1.1		9.4	J	13		15		47		29	J	5		0.13		8.7	J	68	
	SS-MM2	mg/kg	0.84		15	J	11		37		29		56	J	6.6		0.1	U	10	UJ	91	
	SS-MM3	mg/kg	1.2		5.4	J	31		14		83		19	J	2.9		1.1		14	UJ	53	
	SS-MM4	mg/kg	0.42		12	J	9.4	J+	44		26		55	J	4.9		0.099	U	9.9	UJ	56	
	SS-MM5	mg/kg	0.47		7.4	J	7.4	J+	11		24		32	J	2.8		0.087	U	8.7	UJ	44	
Ribbed Mussels	RM-1	mg/kg	0.23	U	7.7		14	J+	2.3		3		5.3	J+	0.54	J+	0.76		23	U	57	
	RM-2	mg/kg	0.24		7.6		16	J+	2		5.1		4.7	J+	0.63	J+	0.71		21	U	64	
	RM-3	mg/kg	0.23		6.1		10.4		1.8		3.3		4.4	J+	0.57	J+	0.38		14	U	41	
	RM-4	mg/kg	0.21	U	7.7		14	J+	2.1		4		6.3	J+	0.62	J+	0.52		21	U	57	
	RM-5	mg/kg	0.19	U	7.7		12	J+	1.3		6		5	J+	0.45	J+	0.48		19	U	53	
	RM-6	mg/kg	0.25		9.5		14.4	J+	1.6		8.6		7.1	J+	0.54	J+	0.38		21	U	59	
Soft Shell Clam (*Mya*)	Mya-1	mg/kg	0.15	U	1.4		8.5	J+	0.67		3.4		4.3	J+	0.36	J+	0.15	U	15	U	21	
	Mya-2	mg/kg	0.4		7.6		21		1.6		15		30		1.3	J+	0.38		27	U	94	
	Mya-3	mg/kg	0.37		6.4		22		1.6		17		130		1.3	J+	0.7		16	U	96	
	Mya-4	mg/kg	1.2		7.3		31		3.1		16		20		1.4	J+	0.5		12	U	86	
	Mya-5	mg/kg	0.33		7.2		24		1.5		14		21		1.7	J+	0.52		13	U	94	
Hard Shell Clam (*Mercenaria*)	Mer-1 (Small)	mg/kg	0.11	U	5.1		14		1.8		1.7		52		1.4	J+	0.19		11	U	69	
	Mer-2 (Medium)	mg/kg	0.11	U	5.9		11		1.6		2.9		200		0.95	J+	0.26		11	U	93	
	Mer-3 (Large)	mg/kg	0.1	U	9.8		14.3		1.2		3.1		120		1.6	J+	2.1		10	U	120	
Foraging Fish (*Fundulis*)	FF-1	mg/kg	0.17	U	3.6		5	J+	1		0.52	J+	13.3		0.34	J+	0.17	U	17	U	80	
	FF-2	mg/kg	0.19	U	3.5		4.8	J+	1		0.92	J+	18		0.39	J+	0.19	U	19	U	93	
	FF-3	mg/kg	0.16	U	3.5		5.9	J+	0.98		0.49	J+	14		0.33	J+	0.16	U	16	U	79	
	FF-4	mg/kg	0.17	U	3.8		6.1	J+	1.1		0.49	J+	17		0.39	J+	0.17	U	17	U	93	
	FF-5	mg/kg	0.29	U	3.7		5	J+	1.3		0.52	J+	15		0.38	J+	0.29	U	29	U	87	
Sea Lettuce (*Ulva*)	Ulva-1	mg/kg	0.23		4.7		12	J+	5		24		120	J-	2.6	J+	0.19	U	19	U	32	
	Ulva-2	mg/kg	0.6		15		9.7	J+	2.6		56		230	J-	4	J+	0.23	U	23	U	51	
	Ulva-3	mg/kg	0.54		10		11	J+	2.8		66		250	J-	4.7	J+	0.18	U	18	U	41	
	Ulva-4	mg/kg	0.57		12		12	J+	4.6		69		280	J-	3.4	J+	0.2	U	20	U	51	
	Ulva-5	mg/kg	0.75		6.3		13	J+	3.4		80		280	J-	3.6	J+	0.21	U	21	U	38.1	

mg/kg=milligram per kilogram dry weight
ug/L=microgram per liter
U=Undetected
J+= Value is estimated high
J= Estimated
UJ= Not detected and reporting limit is estimated
* Soil = Beach Sediments

Table 5. Analytical Results of Soil[a] Samples Collected Along Intertidal Zone Adjacent to Seawall*
Raritan Bay Slag Site
Old Bridge Township, NJ

Sample	Distance from Seawall (ft)	Units	Antimony (Sb)		Arsenic (As)		Copper (Cu)		Chromium (Cr)		Lead (Pb)		Manganese (Mn)		Nickel (Ni)		Silver (Ag)		Tin (Sn)		Zinc (Zn)	
			Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier
RBS-SED17	75	mg/kg		R		R		R	4.9		75.7			R	1.3	J	1.4	U	14.2	UJ	27.6	J
RBS-SED18	75	mg/kg		R		R		R	8.3		186			R	2.7	J	1.6	U	16	UJ	52.7	J
RBS-SED07	25	mg/kg		R		R		R	57		5860			R	18.4		0.24	J	127	J	242	J
RBS-SED08	25	mg/kg		R		R		R	7.1		861			R	3	J	1.3	U	38.6	J	46.3	J
RBS-SED19	75	mg/kg		R		R		R	9.1		93.5			R	3.2	J	1.5	U	15	UJ	43.2	J
RBS-SED09	25	mg/kg		R		R		R	17.3		403			R	2.7	J	1.2	U	14.5	J	47	J
RBS-SED20	75	mg/kg		R		R		R	19.6		58.2			R	7.4		1.5	U	15.2	UJ	59.2	J
RBS-SED21	75	mg/kg		R		R		R	5.7		48.1		17.4	17.4	1.2	J	1.3	U	13.1	UJ	32.2	J
RBS-SED22	75	mg/kg	7.7	UJ	2.4		8.4		6.4		53.6	J	18.7		5.2	U	0.32	J	12.9	UJ	34.9	
RBS-SED10	25	mg/kg		R		R		R	7.4		326			R	3.2	J	1.2	U	12.4	UJ	41.1	J
RBS-SED23	75	mg/kg	8.6	UJ	3.1		9.6		5.5		90.7	J	17.2		5.7	U	0.22	J	14.3	UJ	30.3	
RBS-SED11	25	mg/kg		R		R		R	8.1		441			R	4.4	J	1.4	U	47.8	J	53.8	J
RBS-SED24	75	mg/kg	8.3	UJ	2.9		9.7		6		79.4	J	14.6		5.5	U	1.4	U	13.8	UJ	32.9	
RBS-SED12	25	mg/kg		R		R		R	10.4		660			R	5.8		1.2	U	53.6	J	54.9	J
RBS-SED25	75	mg/kg	13.9	J	6.6		21.2		4.5		458	J	15.5		4.7	U	1.2	U	22.5		29.1	
RBS-SED26	25	mg/kg	20.5	J	15.7		25.4		6.3		525	J	89.5		5.6	U	1.4	U	1020		39.4	
RBS-SED88	75	mg/kg	28	J	19.2		117		5.8		1440	J	13.7		5.6	U	0.14	J	42.1		53.2	
RBS-SED87	25	mg/kg	33.2	J	22.5		37.3		6.7		1100	J	51.6		12.2		0.23	J	45.4		41.1	

* Data from Weston Solutions 2009

a. Soil = Beach Sediments

U= Undetected analyte

J= Estimated concentration

UJ - The analyte was not quantifiable at or above the Contract Required Quantitation Limit (CRQL), or QA/QC requirements were not met

R= Unusable value

N
W E
S
Magnetic North

Map created using New Jersey 2007 color orthophotography.

Map Creation Date: 17 March 2009

Coordinate system: New Jersey State Plane
FIPS: 2900.
Datum : NAD83.
Units : Feet.

800 0 800 1,600 2,400
Feet

Legend

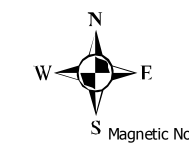
Sea Wall

Data: g:\arcviewprojects\reac4\00-356
MXD file: g:\arcinfoprojects\reac4\EAC00356_LaurebceHarbor\356_SiteOverview_fXrev002
Revision Number: 002

U.S EPA Environmental Response Team
Response Engineering and Analytical Contract
EP-C-04-032
W.A.# 0-356

Figure 1
Site Overview
Raritan Bay Slag Site
Old Bridge Township, New Jersey
March, 2009

R2-0006835



Legend

Sampling Locations

- MYA 1 to 5
- RM 1 to 6
- ULVA 1 to 5
- Mercenaria 1 to 3
- Killifish 1 to 5

Map created using New Jersey 2007 color orthophotography , site GPS survey data.

Map Creation Date: 18 May 2009

Coordinate system: New Jersey State Plane
FIPS: 2900.
Datum : NAD83.
Units : Feet.

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Feet

Data: g:\arcviewprojects\reac4\00-356
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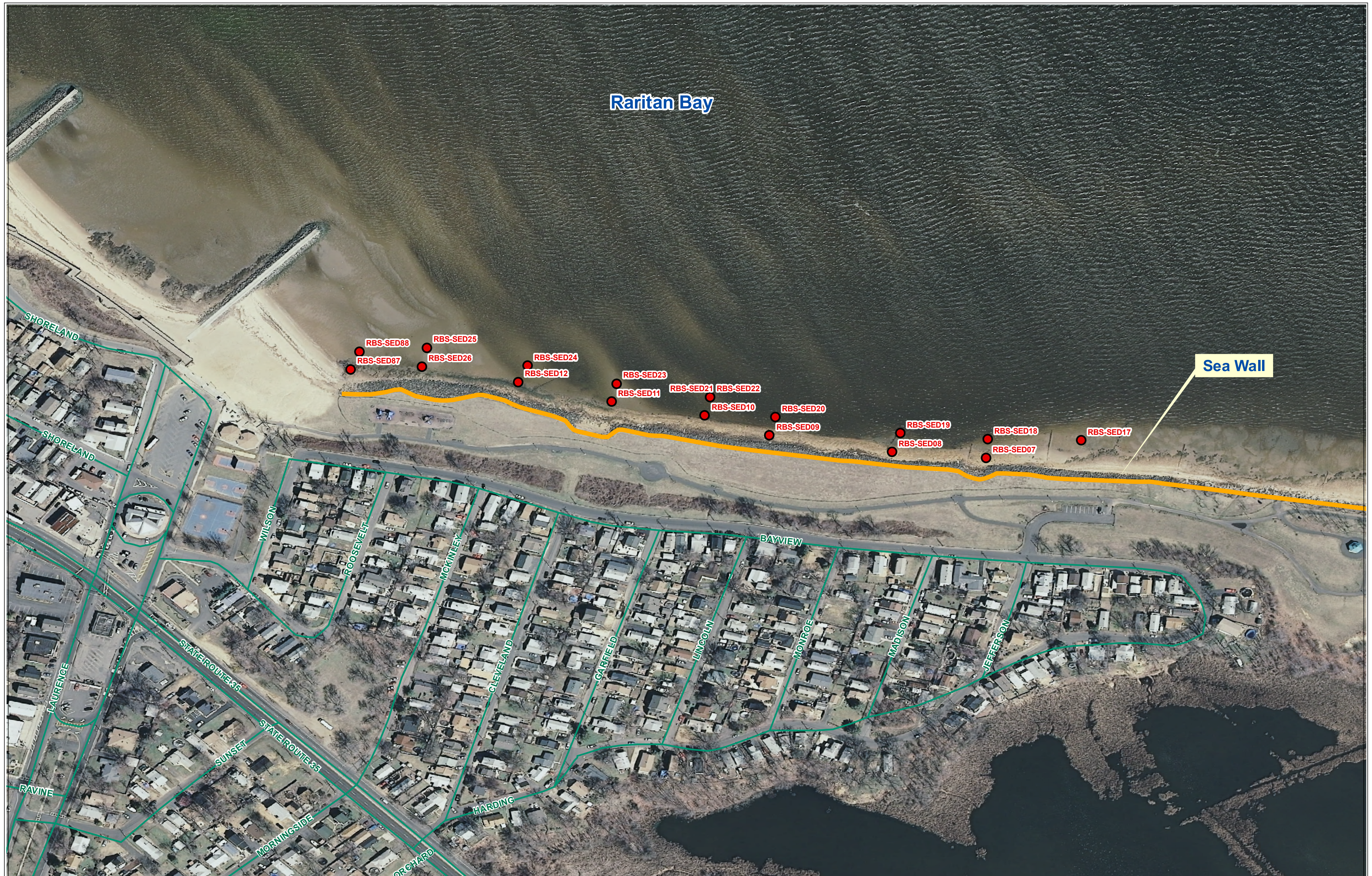
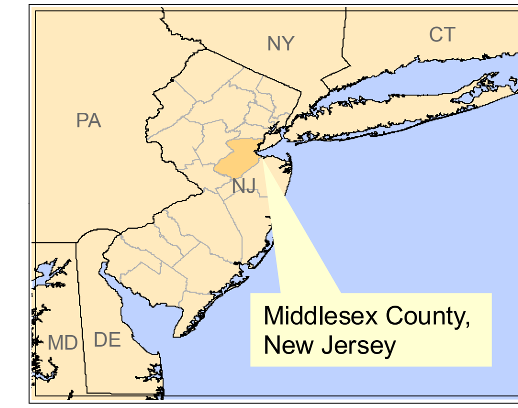
Revision Number: 002

U.S EPA Environmental Response Team
Response Engineering and Analytical Contract
EP-C-04-032
W.A.# 0-356

Figure 2
Sampling Locations
Raritan Bay Slag Site
Old Bridge Township, New Jersey
May, 2009

R2-0006836





N
W E
S
Magnetic North

Legend

- Sample Location
- Sea Wall

Map created using New Jersey 2007 color orthophotography , site GPS survey data.

Map Creation Date: 18 May 2009

Coordinate system: New Jersey State Plane
FIPS: 2900.
Datum : NAD83.
Units : Feet.

300 0 300 600
Feet

Data: g:\arcviewprojects\reac4\00-356
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Revision Number: 001

U.S EPA Environmental Response Team
Response Engineering and Analytical Contract
EP-C-04-032
W.A.# 0-356

Figure 3
Soil Sampling Location
Raritan Bay Slag Site
Old Bridge Township, New Jersey
May, 2009

R2-0006837

Figure 4: Intertidal Zone Along Seawall

Figure 5: Seawall Slag at High Tide

Figure 6: Cheesequake Creek Inlet Western Jetty at High Tide

Figure 7: Cheesequake Creek Inlet Western Jetty

Figure 8: Slag at Cheesequake Creek Inlet Western Jetty

Figure 9: Slag and Fragments

Figure 10: Beachfront Area West of Jetty

Figure 11: *Spartina* (Cordgrass) Along Seawall at Low Tide

Figure 12: Ribbed Mussels

Figure 13: *Mya* (Steamer) Clam

APPENDIX A

ANALYTICAL REPORT: CHARACTERIZATION OF SLAG

OHIO STATE UNIIVERSITY

Raritan Bay Slag and Soil Characterizations

E.A. Dayton, S.D. Whitacre
School of Environment and Natural Resources
The Ohio State University
March, 2009

Project Summary:

Seventeen waste rock samples and ten sediment samples were characterized for As, Pb, Cu, Sn, Zn, and Sb. Elemental content was determined for all twenty-seven samples, while solubility and leachability were determined on only the seventeen waste rock samples. Additional spectroscopic investigation was performed on all twenty-seven samples in order to identify possible mineral phases in the waste rock and sediment.

The twenty-seven samples varied widely in elemental content (Table 1), indicating that the Raritan Bay waste rock and sediment contaminant concentrations are very heterogeneous.

Table 1. Minimum (min), maximum (max), and median elemental content of Raritan Bay waste rock and sediment (US EPA 3051A).

Element	Unit	min	max	median
As	g/kg	0.00313	15.2	1.62
Cu	g/kg	0.00477	445	3.27
Pb	g/kg	0.0358	173	60.2
Sb	g/kg	0.00976	71.3	3.19
Sn	g/kg	0.00416	11.4	4.54
Zn	g/kg	0.00917	13.5	2.02

Methods:

The samples were oven dried at 60°C followed by pulverization to powder in a puck mill and homogenization. Elemental content was determined by US EPA method 3051A (SOP attached); solubility was determined with a neutral salt (0.01M $CaCl_2$) extraction (SOP attached); and leachability by the toxicity characteristic leaching procedure (SOP attached). Particle size of the powdered samples was further reduced using an agate mortar and pestle prior to X-ray diffraction (XRD). The XRD analysis was carried out using a Scintag XDS2000 diffractometer equipped with a θ-θ goniometer, a 2kW sealed-beam tube with Cu anode and Si-Ge solid-state detector. Samples were pressed into Plexiglas specimen mounts and scanned according to the instrumental settings given in Table 2. The raw scans were collected using the Scintag DMS2000 Diffraction Management Software (Sunnyvale, CA).

Table 2. X-ray diffractometer settings

Scan range	2-80°2θ
Tube voltage	45kV
Filament current	20mA
Source collimating slits	2 & 4mm
Detector receiving slits	0.5 & 0.3mm
Scan mode	continuous
Scan rate	1°min^{-1}
Scan interval	0.03°2θ

Pattern processing and phase identification were carried out using MDI (Materials Data Inc., Livermore, CA) Jade ver. 6.1 (preferences given in Table 3 below). A background function was fitted and subtracted from each of the raw scans. Phase identification by search/match routine was launched on the reduced pattern.

Table 3. Peak Search and Background Fitting Preferences

Peak Search Filter Points	15
Peak Search Filter Type	Parabolic
Peak Location	by summit
$K_{\alpha 2}$ peaks	screened out
Threshold sigma	3.0
Intensity cutoff %	0.10
Background fitting function	cubic spline
Background fitting point sampling	dense
Background fitting vertical offset	0.4

The Powder Diffraction File (PDF) maintained by the International Center for Diffraction Data (ICDD) & the Inorganic Crystal Structure Database (ICSD) which include NBS and common phases were accessed during the search/match routine. A preferred orientation filter was invoked to compensate for particle orientations acquired during packing of the specimen holder. A 2θ error window of 0.06 and 2θ position and intensity matching sensitivities of 4 and 6 respectively were used. Phases were sorted by figure of merit and selected/rejected based on visual match to the pattern. Phase selections were further guided by results from the dissolution chemistry.

Tables 1 to 4 provide the results.

Standard Operating Procedure
3051a Microwave Assisted Acid Digestion of Sediments, Sludges, and Soils Followed by Inductively Coupled Plasma (ICP) Spectrometry analysis
Soil Environmental Chemistry Program, The Ohio State University
Version 2

1.0 Scope of Method

1.1 This method is a microwave-assisted extraction using aqua regia and HNO_3. This method is more aggressive in dissolving the sample matrix than methods using conventional heating with nitric acid (HNO_3), or alternatively, nitric acid and hydrochloric acid (HCl), according to EPA Methods 200.2 and 3050. However, because Method 3051a does not accomplish total decomposition of the sample, the extracted analyte concentrations may not reflect the total content in samples where the analytes are occluded in recalcitrant mineral phases. This method is applicable to the microwave-assisted acid extraction/dissolution‡ of sediments, sludges, and soils, for the following elements: Aluminum (Al)*, Antimony (Sb)*, Arsenic (As), Barium (Ba)*, Beryllium (Be)*, Boron (B), Cadmium (Cd), Calcium (Ca), Chromium (Cr)*, Cobalt (Co), Copper (Cu), Iron (Fe)*, Lead (Pb), Magnesium (Mg)*, Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Potassium (K), Selenium (Se), Silver (Ag)*, Sodium (Na), Strontium (Sr), Thallium (Tl), Vanadium (V)*, Zinc (Zn).
*Indicates elements which typically require the addition of HCl to achieve equivalent results with EPA Method 3050, as noted in reference 3.
This method is intended to provide a rapid multi-element acid extraction or dissolution prior to analysis. Many types of samples will be dissolved by this method. A few refractory sample matrix compounds, such as quartz, silicates, titanium dioxide, alumina, and other oxides may not be dissolved and in some cases may sequester target analyte elements. These bound elements are considered non-mobile in the environment and are excluded from most aqueous transport mechanisms of pollution.

2.0 Definitions

2.1 Laboratory Control Sample: The laboratory control used for the microwave digestion is a standard reference material (SRM) or certified reference material (CRM) that goes through the same extraction/preparation procedure as the samples. The analyte composition of the laboratory control sample is certified by acid dissolution method 3051a, 3050, or equivalent.

2.2 Duplicate Samples: A duplicate test involves splitting a sample two sub-samples and processing each through the same sample preparation procedure in order to determine the precision of the method.

2.3 Pre-digestion Spike: A duplicate sample is spiked prior to digestion in order to provide information about the effect of the sample matrix on the digestion and/or measurement methodology.

2.4 Preparation Blank: The Preparation Blank is a sample that contains only the reagents used in the extraction procedure. The preparation blanks is processed through the same preparation procedures as the samples and therefore gives an indication of any contamination picked up during the sample preparation process.

2.5 Serial Dilution: A serial dilution consists of a comparison of the results of a sample and another aliquot diluted by a known factor.

2.6 ICP-AES: Inductively Coupled Plasma-Atomic Emission Spectrometry.

2.7 ICP-HG-AES: ICP-AES with sample introduction using automated hydride generation

2.8 ICP-MS: Inductively Coupled Plasma-Mass Spectrometry.

3.0 Equipment and Supplies

3.1 MARS 1600 watt microwave (CEM corporation, Mathews, NC).
Note: The microwave power output test, power calibration, and temperature probe calibration should be performed according to manufactures specifications every six months.

3.2 Trace metal grade nitric acid.

3.3 Trace metal grade hydrochloric acid.

3.4 ≥18 MΩ deionized water (DI).

3.5 50ml volumetric flasks

3.6 Parafilm

4.0 Procedure
Review SOP for handling acids (attached) prior to beginning the procedure.

4.1 Weigh a well-mixed sample to the nearest 0.001 g into an acid washed Teflon vessel equipped with a controlled pressure relief mechanism.

4.2 Add 9.0 ± 0.1 mL concentrated nitric acid and 3.0 ± 0.1 mL concentrated hydrochloric acid to the vessel in a fume hood.

4.2a The addition of concentrated hydrochloric acid to the nitric acid is appropriate for the stabilization of certain analytes, such as Ag, Ba, and Sb and high concentrations of Fe and Al in solution.

4.3 Seal the vessel according to the manufacturer's directions. Properly place the vessel in the microwave system according to the manufacturer's recommended specifications.

4.4 Enable the appropriate 3051 method in the MARS unit software as determined by the number of samples and project requirements. Note: The 3051_40 express method does not adhere to the 4 minute ramp requirement of the USEPA 3051 method.

4.5 Once the digests have cooled, remove from the microwave and wholly transfer into labeled 50ml volumetrics that have been acid washed following the *Dish Washing SOP* and triple rinsed with ≥18 MΩ DI water immediately prior to transfer.

4.6 Bring samples to volume, cover with parafilm and mix thoroughly by inversion. Bring to volume and mix thoroughly again after samples have cooled.

4.7 Syringe filter samples into labeled falcon tubes using dry acid washed syringes and nylon 0.45um nylon syringe filters.

5.0 Quality Control

5.1 Laboratory Control Sample: The laboratory control sample must fall within ± 20% of the known value or within the 95% prediction interval of the certified value. The laboratory control sample must be run with each batch of microwave digestions.

5.2 Sample Duplicates: The relative percent difference (RPD) must be no more than 20%. One sample duplicate must be run with every microwave batch.

$$RPD = 100 \times \frac{|S - D|}{Avg.(S,D)}$$

5.3 Pre-digestion Spike: Spike recoveries must fall within the limits of 75-125%. At least one spike analyses (matrix spikes) shall be performed on each group of samples of a similar matrix type. Pre-digestion spikes are to be done at the following levels for elements of interest.

Final Spike concentration	mg/L spike solution	uL spike prior to digest
As - 400 mg/kg	1000	200
Ba - 400 mg/kg	1000	200
Se 400 mg/kg	1000	200
Tl - 400 mg/kg	1000	200
Sb - 100 mg/kg	1000	50
Co 100 mg/kg	1000	50

Pb - 100 mg/kg	1000	50
Mn - 100 mg/kg	1000	50
Ni - 100mg/kg	1000	50
V - 100 mg/kg	1000	50
Zn - 100 mg/kg	1000	50
Cu 50 mg/kg	1000	25
Cr 40 mg/kg	1000	20
Ag - 10 mg/kg	100	50
Be - 10 mg/kg	100	50
Cd 10 mg/kg	100	50

5.4 Preparation Blank: If any analyte concentration is above the detection limit, in the preparation blank, the lowest concentration of the analyte reported in associated samples must be ≥ 10 times the preparation blank concentration. A preparation blank must be performed with each batch of microwave digests.

5.5 Serial Dilution: The % difference for the serial dilution tests must be no more than 10%. At least one serial dilutions should be performed on each group of samples with similar matrix.

$$\%Difference = 100 * [initial] - \frac{([diluted] * DilutionFactor)}{[initial]}$$

6.0 Instrumental Analysis

6.1 Instrumentation: ICP-AES and ICP-HG-AES analysis are carried out on a Varian Vista-MPX ICP-OES (Varian Inc., Walnut Creek, CA). Determination by ICP-MS is done on a Perkin-Elmer Sciex ELAN 6000 (Perkin-Elmer Inc., Waltham, MA)

6.2 Detection Limits

6.2a Method detection limits (MDL) are calculated for specific methods and consequent conditions of that method developed for analysis on ICP. The method detection limit is determined by multiplying by 3.143 the standard deviation of seven replicate analyses of standard solutions at 2-5x the IDL limit.

6.3 Stock standards are prepared using ICP grade standards (SPEX CertiPrep Group, Metuchen, NJ, Assurance ICP Standards). Calibration standards are prepared daily by serial dilution from at least two independent stock standards. The dilutions should be done into a matrix comparable to the samples.

6.4 Nebulizer optimization should be performed before each calibration. Nebulizer optimization should be carried out according to manufacturer specifications.

6.5 Instruments shall be calibrated daily and each time the instrument is set up. Calibrate the instrument according to instrument manufacturer's recommended procedures. At least four standards shall be used for ICP calibration. One of the standards shall be a blank. Linear calibration must meet the criteria of: $r^2 = 0.995$, and calculated concentrations from the regression within 10% for each standard in the calibration.

6.6 Initial calibration verification (ICV) is an independent certified mixed QC standard (SPEX CertiPrep Group LPC standard 1, Fisher Cat. No. LPC-1-100N) run immediately after instrument calibration. Standards must fall within ± 10% of certified value. An independent standard is defined as a standard composed of the analytes from a different source than those used in the standards for the instrument calibration.

6.7 Continuing calibration verification (CCV) is a dilution of the ICV QC standard and is run after every ten samples. Standards must fall within ± 10% of certified value.

6.8 Initial calibration blank (ICB) is a calibration blank run just prior to the first sample. The calibration blank must fall below the method detection limit (MDL) detection limit. If the calibration blank is above the MDL, the problem should be fixed and instrument re-calibrated.

6.9 Continuing calibration blank (CCB) is a calibration blank run after every ten samples with the CCV. The calibration blank must fall below the MDL. If a calibration blank is above the detection limit, the instrument must be recalibrated and the previous samples to the last CCB re-run.

6.10 Limit of quantitation (LOQ) is a check standard used to verify linearity at the MDL for ICP analysis. The LOQ standards at a concentration equal to the MDL are analyzed at the beginning and end of each sample analysis and at a frequency of not greater than 20 analytical samples.

6.11 A linear range verification check standard shall be analyzed for each wavelength concentrations that exceed the highest calibration standard by more than 20%. The standard shall be analyzed during the analytical run. The analytically determined concentration of this standard shall be within 10% of the true value. This concentration is the upper limit of the ICP linear range beyond which results cannot be reported without dilution of the analytical sample.

6.12 Potential interferences are determined by calibration of all potential lines used for analysis followed by the analysis of single element standards as samples containing 10 to 500mg/L. Interferences were identified as a signal greater than the IDL on any line other than the element in the standard. The single element standards investigated included; Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Tl, V, Zn.

6.13 To verify interelement and background correction factors for the ICP, an Interference Check Samples (ICS) shall be analyzed at the beginning and end of each analysis run and not greater than 20 analytical samples per analysis run. The Interference Check Samples consist of two solutions: Solution A and Solution AB. Solution A consists of the interferents, and Solution AB consists of the analytes mixed with the interferents. An ICS analysis consists of analyzing both solutions consecutively (starting with Solution A) for all wavelengths used for each analyte reported by ICP. The analytical results for those target analytes with MDLs < 10 ug/L shall fall within + 2x MDL of the analyte's true value (the true value shall be zero unless otherwise stated) in the ICS Solution A (ICSA). For example, if the analysis result(s) for Arsenic (MDL = 10 ug/L, ICSA true value = 0 ug/L) in the ICSA analysis during the run is + 19 ug/L, then the analytical result for Arsenic falls within the + 2x MDL window for Arsenic in the ICSA. Results for the ICP analyses of Solution AB during the analytical runs shall fall within the control limit of +20% of the true value for the analytes included in the Interference Check Samples. If not, terminate the analysis, correct the problem, recalibrate the instrument, and reanalyze the analytical samples analyzed since the last good ICS. This + 20% window does not apply when the IDL exceeds the MDL for the analytes As, Pb, Se, Tl.

INTERFERENT AND ANALYTE ELEMENTAL CONCENTRATIONS USED FOR ICP INTERFERENCE CHECK SAMPLE

Analytes (mg/L)		Interferents (mg/L)
ICS B		ICS A & ICS B
Se 0.05	Tl 0.1	Al 500
As 0.1	Zn 1.0	Ca 500
Ba 0.5		Fe 200
Be 0.5		Mg 500
Cd 1.0		
Co 0.5		
Cr 0.5		
Cu 0.5		
Mn 0.5		
Ni 1.0		
Pb 0.05		

7.0 Reporting

7.1 If the QC limits are not met for any element or sample, the effect on the data set will be evaluated by the project manager and analyst.

8.0 References

8.1 United States Environmental Protection Agency. Method 3051A. Microwave assisted acid digestion of sediments, sludges, soils, and oils. In SW-846; U.S. EPA: Washington, DC, 1998.

8.2 United States Environmental Protection Agency. Method 6010C. Inductively Coupled Plasma-Atomic Emission Spectrometry. In SW-846; U.S. EPA: Washington, DC, 2007.

8.3 United States Environmental Protection Agency. Method 6020A. Inductively Coupled Plasma-Atomic Mass Spectrometry. In SW-846; U.S. EPA: Washington, DC, 2007.

8.4 United States Environmental Protection Agency. Document number ILM04.0b. Contract Laboratory Program Statement of work for inorganic analysis, multi-media, multi-concentration. U.S. EPA: Washington, DC.

Standard Operating Procedure
Neutral Salt Extraction
Soil and Environmental Chemistry Group, The Ohio State University, Version 2

1.0 Scope of Method

1.1 A neutral salt extraction is used to screen for elemental solubility.

1.2 This method is applicable for testing soil, sediments, and municipal/industrial byproducts

3.0 Definitions

2.1 Duplicate Samples: A duplicate test involves splitting a sample into two or more sub-samples and processing each through the same sample preparation procedure in order to determine the precision of the method.

2.2 Preparation Blank: A a sample that contains only the reagents used in the extraction procedure. The preparation blank~~s~~ is processed through the same procedures as samples and therefore gives an indication of potential contamination in the sample preparation process.

2.3 ICP-AES: Inductively Coupled Plasma-Atomic Emission Spectrometry.

3.0 Equipment and Supplies

3.1 Shaker

3.2 Neutral salt solution

3.4 ≥18 MΩ deionized water.

4.0 Procedure

4.1 Samples should be oven dried 70 ºC, dried and crushed to <2mm

4.2 Weigh 5 g of well-mixed sample to the nearest 0.001 g into a 50 mL centrifuge tube

4.3 Add 25 mL of 0.01 *M* $CaCl_2$ solution and cap vessel

4.4 Equilibrate sample by shaking for 4h

4.5 Filter (0.45µm) using nylon syringe filters, into ICP falcon tubes

4.6 Refrigerate filtered extracts and analyze within 2 days or add 1drop concentrated HCl to preserve samples.

5.0 Quality Control

5.1Sample Duplicates: The % relative standard deviation (%RPD) must be no more than 20%. One sample duplicate must be run for every twenty samples.

$$RPD = 100 \times \frac{|S - D|}{\text{Avg. }(S,D)}$$

5.2 Preparation Blank: If any analyte concentration is above the detection limit, the lowest concentration of the analyte in the associated samples must be 10 times the preparation blank concentration. A preparation blank must run every 10 samples

6.0 Instrumental Analysis by ICP-OES

6.1 Instrumentation: ICP-AES and ICP-HG-AES analysis are carried out on a Varian Vista-MPX ICP-OES (Varian Inc., Walnut Creek, CA).

6.2 Stock standards are prepared using ICP grade standards (SPEX CertiPrep Group, Metuchen, NJ, Assurance ICP Standards). Calibration standards are prepared daily by serial dilution from at least two independent stock standards. The dilutions should be done into a matrix comparable to the samples.

6.3 Nebulizer optimization should be performed before each calibration. Nebulizer optimization should be carried out according to manufacturer specifications.

6.4 Instruments shall be calibrated daily and each time the instrument is set up. Calibrate the instrument according to instrument manufacturer's recommended procedures. At least four standards shall be used for ICP calibration. One of the standards shall be a blank. Linear calibration must meet the criteria of: $r^2 = 0.995$, and calculated concentrations from the regression within 10% for each standard in the calibration.

6.5 Initial calibration verification (ICV) is an independent certified mixed QC standard (SPEX CertiPrep Group LPC standard 1, Fisher Cat. No. LPC-1-100N) run immediately after instrument calibration. Standards must fall within ± 10% of certified value. An independent standard is defined as a standard composed of the analytes from a different source than those used in the standards for the instrument calibration.

6.6 Continuing calibration verification (CCV) is a dilution of the ICV QC standard and is run after every ten samples. Standards must fall within ± 10% of certified value.

6.7 Initial calibration blank (ICB) is a calibration blank run just prior to the first sample. The calibration blank must fall below the method detection limit (MDL) detection limit. If the calibration blank is above the MDL, the problem should be fixed and instrument re-calibrated.

6.8 Continuing calibration blank (CCB) is a calibration blank run after every ten samples with the CCV. The calibration blank must fall below the MDL. If a calibration blank is above the detection limit, the instrument must be recalibrated and the previous samples to the last CCB re-run.

6.9 Limit of quantitation (LOQ) is a check standard used to verify linearity at the MDL for ICP analysis. The LOQ standards at a concentration equal to the MDL are analyzed at the beginning of each sample analysis.

6.10 A linear range verification check standard shall be analyzed for each wavelength concentrations that exceed the highest calibration standard by more than 20%. The standard shall be analyzed during the analytical run. The analytically determined concentration of this standard shall be within 10% of the true value. This concentration is the upper limit of the ICP linear range beyond which results cannot be reported without dilution of the analytical sample

6.11 Potential interferences are determined by calibration of all potential lines used for analysis followed by the analysis of single element standards as samples containing 10 to 500mg/L. Interferences were identified as a signal greater than the IDL on any line other than the element in the standard. The single element standards investigated included; Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Tl, V, Zn.

7.0 Reporting

7.1 If the QC limits are not met for any element or sample, the effect on the data set will be evaluated by the project manager and analyst.

8.0 References

8.1 U.S. Environmental Protection Agency. Method 6010C. Inductively Coupled Plasma-Atomic Emission Spectrometry. In SW-846; U.S. EPA: Washington, DC, 2007.

8.2 U.S. Environmental Protection Agency. Document number ILM04.0b. Contract Laboratory Program Statement of work for inorganic analysis, multi-media, multi-concentration. U.S. EPA: Washington, DC.

Toxicity Characteristic Leaching Procedure (TCLP) for Inorganics
Standard Operating Procedure
Soil Environmental Chemistry Program, The Ohio State University
Version 1

1.0 Scope of Method

1.1 The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes.

2.0 Definitions

2.1 Duplicate Samples: A duplicate test involves splitting a sample two sub-samples and processing each through the same sample preparation procedure in order to determine the precision of the method.

2.2 Preparation Blank: The Preparation Blank is a sample that contains only the reagents used in the extraction procedure. The preparation blanks is processed through the same preparation procedures as the samples and therefore gives an indication of any contamination picked up during the sample preparation process.

2.3 Matrix Spike: A duplicate sample is spiked after to the extraction procedure in order to provide information about the effect of the sample matrix on the measurement methodology.

2.4 ICP-AES: Inductively Coupled Plasma-Atomic Emission Spectrometry.

3.0 Equipment and Supplies

3.1 Agitation apparatus

3.2 high density polyethylene (HDPE), polypropylene (PP), or polyvinyl chloride(PVC) extraction vessels

3.3 pH Meter accurate to 0.05 units

3.4 Laboratory Balance: Any laboratory balance accurate to within + 0.01 grams may be used (all weight measurements are to be within + 0.1 grams).

3.5 Hydrochloric acid (1N), HCl, made from ACS reagent grade.

3.6 Nitric acid (1N), HNO3, made from ACS reagent grade.

3.7 Sodium hydroxide (1N), NaOH, made from ACS reagent grade.

3.8 Glacial acetic acid, CH3CH2OOH, ACS reagent grade.

3.9 ≥18 MΩ deionized water (DI).

3.10 Parafilm

4.0 Procedure

Review SOP for handling acids (attached) prior to beginning the procedure.

4.1 Oven dry sample at 60°C.

4.2 Grind solid sample until it is capable of passing through a 9.5 mm sieve.

4.3 Determine the correct extraction solution for the sample.

4.3.1 Weigh 5g of sample into a 500 mL beaker or Erlenmeyer flask. Add 96.5 mL of reagent water to the beaker, cover with a watchglass, and stir vigorously for 5 minutes using a magnetic stirrer. Measure and record the pH. If the pH is <5.0, use extraction fluid #1. If the pH from Section 7.1.4.2 is >5.0, add 3.5 mL 1N HCl, slurry briefly, cover with a watchglass, heat to 50 °C, and hold at 50 EC for 10 minutes. Let the solution cool to room temperature and record the pH. If the pH is <5.0, use extraction fluid #1. If the pH is >5.0, use extraction fluid #2.

4.4 Prepare appropriate extraction solution.

Extraction fluid # 1: Add 5.7 mL glacial CH_3CH_2OOH to 500 mL of reagent water (See Section 5.2), add 64.3 mL of 1N NaOH, and dilute to a volume of 1 liter. When correctly prepared, the pH of this fluid will be 4.93 + 0.05.

Extraction fluid # 2: Dilute 5.7 mL glacial CH_3CH_2OOH with reagent water (See Section 5.2) to a volume of 1 liter. When correctly prepared, the pH of this fluid will be 2.88 + 0.05

4.5 Weigh 1.5g of sample into extraction vessel.

4.6 Add 30ml of extraction fluid

4.7 Close the extractor bottle tightly, secure in agitation device, and agitate for 18 ± 2 hours.

4.8 Remove from rotary agitation device and 0.45um nylon syringe filter (aprox. 12ml) into falcon tubes for ICP analysis. Samples should be preserved <pH 2 by the addition of 1 drop of concentrated HNO_3.

5.0 Instrumental Analysis by ICP-OES

5.1 Instrumentation: ICP-AES and ICP-HG-AES analysis are carried out on a Varian Vista-MPX ICP-OES (Varian Inc., Walnut Creek, CA). Determination by ICP-MS is done on a Perkin-Elmer Sciex ELAN 6000 (Perkin-Elmer Inc., Waltham, MA)

5.2 Stock standards are prepared using ICP grade standards (SPEX CertiPrep Group, Metuchen, NJ, Assurance ICP Standards). Calibration standards are prepared daily by serial dilution from at least two independent stock standards. The dilutions should be done into a matrix comparable to the samples.

5.3 Nebulizer optimization should be performed before each calibration. Nebulizer optimization should be carried out according to manufacturer specifications.

5.4 Instruments shall be calibrated daily and each time the instrument is set up. Calibrate the instrument according to instrument manufacturer's recommended procedures. At least four standards shall be used for ICP calibration. One of the standards shall be a blank. Linear calibration must meet the criteria of: $r^2 = 0.995$, and calculated concentrations from the regression within 10% for each standard in the calibration.

5.5 Initial calibration verification (ICV) is an independent certified mixed QC standard (SPEX CertiPrep Group LPC standard 1, Fisher Cat. No. LPC-1-100N) run immediately after instrument calibration. Standards must fall within ± 10% of certified value. An independent standard is defined as a standard composed of the analytes from a different source than those used in the standards for the instrument calibration.

5.6 Continuing calibration verification (CCV) is a dilution of the ICV QC standard and is run after every ten samples. Standards must fall within ± 10% of certified value.

5.7 Initial calibration blank (ICB) is a calibration blank run just prior to the first sample. The calibration blank must fall below the method detection limit (MDL) detection limit. If the calibration blank is above the MDL, the problem should be fixed and instrument re-calibrated.

5.8 Continuing calibration blank (CCB) is a calibration blank run after every ten samples with the CCV. The calibration blank must fall below the MDL. If a calibration blank is above the detection limit, the instrument must be recalibrated and the previous samples to the last CCB re-run.

5.9 Limit of quantitation (LOQ) is a check standard used to verify linearity at the MDL for ICP analysis. The LOQ standards at a concentration equal to the MDL are analyzed at the beginning of each sample analysis.

5.10 A linear range verification check standard shall be analyzed for each wavelength concentrations that exceed the highest calibration standard by more than 20%. The standard shall be analyzed during the analytical run. The analytically determined concentration of this standard shall be within 10% of the true value. This concentration is the upper limit of the ICP linear range beyond which results cannot be reported without dilution of the analytical sample

5.11 Potential interferences are determined by calibration of all potential lines used for analysis followed by the analysis of single element standards as samples containing 10 to 500mg/L. Interferences were identified as a signal greater than the IDL on any line other than the element in the standard. The single element standards investigated included; Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Tl, V, Zn.

6.0 Quality Control

6.1 Sample Duplicates: The relative percent difference (RPD) must be no more than 20%. One sample duplicate must be run every 20 samples.

$$RPD = 100 \times \frac{|S - D|}{\text{Avg. }(S,D)}$$

6.2 Matrix Spike: Spikes should be performed such that the end concentration is within the linear range for the instrument. Spike recoveries for analytes of interest must fall within the limits of 75-125%. At least one spike analyses (matrix spikes) shall be performed on each group of samples of a similar matrix type.

6.3 Preparation Blank: If any analyte concentration is above the LOQ, in the preparation blank, the lowest concentration of the analyte reported in associated samples must be ≥ 10 times the preparation blank concentration. A preparation blank must be performed with each batch of microwave digests.

7.0 Reporting

7.1 If the QC limits are not met for any element or sample, the effect on the data set will be evaluated by the project manager and analyst.

8.0 References

8.1 United States Environmental Protection Agency. Method 1311. Toxicity Characteristic Leaching Procedure. In SW-846; U.S. EPA: Washington, DC, 2007.

8.2 United States Environmental Protection Agency. Method 6010C. Inductively Coupled Plasma-Atomic Emission Spectrometry. In SW-846; U.S. EPA: Washington, DC, 2007.

8.3 United States Environmental Protection Agency. Document number ILM04.0b. Contract Laboratory Program Statement of work for inorganic analysis, multi-media, multi-concentration. U.S. EPA: Washington, DC.

APPENDIX B

Work Plan for Work Assignment No. 0-356

Analytical Report by Lockheed Martin, Inc.

WORK PLAN

FOR

WORK ASSIGNMENT NO. 0-356

LAURENCE HARBOR SITE

August 26, 2008

0356-DWP-082608

WORK PLAN
LAURENCE HARBOR SITE

Prepared for
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA)/
ENVIRONMENTAL RESPONSE TEAM (ERT)

Date:	August 26, 2008
Contract No:	EP-C-04-032
Assignment No.:	0-356

Approval:

REAC Task Leader	[signature]	**Date:** 8/27/08
REAC Group Leader (Cost Model Review)	[signature]	**Date:** 8/27/08
REAC Program Manager	[signature]	**Date:** 8/27/08

Lockheed Martin REAC
GSA Raritan Depot
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BLDG 209 Annex
Edison, New Jersey 08837-3679

0356-DWP-082608

Work Assignment Number:	**0-356**
Work Assignment Title:	**Laurence Harbor Site**
Work Assignment Manager:	**Mark Sprenger**
Lockheed Martin REAC Task Leader:	**Larry A. Lyons**
Duration:	**August 6, 2008 thru May 31, 2009**
Contract No:	**EP-C-04-032**
Site ID:	**02ZZ**

INTRODUCTION

Purpose. Under this work assignment (WA), Response Engineering and Analytical Contract (REAC) personnel will provide technical support to the Environmental Protection Agency /Environmental Response Team (EPA/ERT) and EPA Region II for the Laurence Harbor Site in Old Bridge Township, New Jersey (NJ). The intent of this WA is to document adverse ecological and/or human health impact for justification of removal action and Site listing. Technical support will involve the collection of biological samples (worms, ribbed mussels, green algae, foraging fish and clams), co-located sediment samples, waste material samples from the jetties and sea wall and pore water samples, and also to conduct a Toxicity Characteristic Leaching Procedure (TCLP)-metals analysis on the waste material. The waste material will be subjected to metal speciation analysis: all other samples will be analyzed for metals including tin (Sn). The data will be used to support an ecological risk assessment (ERA).

Background. The Laurence site is comprised of a seawall area, Cheesequake Creek outlet jetties and a beach area located in the Raritan Bay at the outlet of the Cheesequake Creek. Contaminants of Concern (COCs) are primarily metals including lead (Pb), arsenic (As), copper (Cu), zinc (Zn), antimony (Sb) and Sn originating from foundry bottoms and battery waste, and potentially other materials. The waste material was used to construct the jetties and was used as a fill and stabilizing material for the seawall.

For the ERA, dietary exposure to site COCs is expected to be the most important exposure pathway. This WA will focus on assessing the bioaccumulation of COCs within the forage (food) items of the ecological receptors at this site, specifically shore birds. Polycheate worms, ribbed mussels, foraging fish, algae and clams are the food items that will be evaluated for the accumulation of COCs. The accumulation of COCs in these forage items (*i.e*, clams) may also present human health risk concerns; however, this will not be addressed as part of this WA.

General Assumptions. Assumptions concerning the scope of work, deliverable and task dates and cost were made on the basis of existing knowledge of the project. New information and data, additional tasks and events outside REAC control may result in revisions to the approach and schedule proposed in this Work Plan (WP). Changes in project schedule, REAC project priorities and available resources may also affect the specific details of this WP. The estimated costs to complete this project (including but not limited to labor, materials, analyses and travel) were developed based on the current scope of work and may change as the project evolves.

If site conditions are not amenable, investigators, with the concurrence of the Task Leader (TL) and the Work Assignment Manager (WAM) will determine the appropriate mode of action in the field (e.g., altered methods, alternate locations). Any changes to the procedures outlined below will be recorded on a Work Assignment Field Change Form and signed by the WAM.

TECHNICAL APPROACH

Task 1: Develop a Field Sampling Plan. REAC personnel will develop a plan to sample biota, sediments, pore water and waste material within the Laurence Harbor site in proximity to the seawall, the Cheesequake jetties and the beach. All sampling will follow REAC standard operating procedures (SOPs) for sample collection as specified in the site-specific Quality Assurance Project Plan (QAPP). All tissue samples will be homogenized at the REAC Biology Laboratory. All sample analyses will be performed by outside analytical laboratories.

Task 2: Provide Field Sampling Support. REAC personnel will provide field sampling services as follows:

> **Task 2.1: Polycheate Worms and Co-Located Sediments.** Five composite samples of polycheate worms and five co-located sediment samples will be collected. The worms will be kept alive and brought back to the REAC Biology Laboratory for a depuration period up to 24 hours. Following the depuration period the worms will be frozen and then homogenized for tissue analyses. All samples will be analyzed for Target Analyte List (TAL) metals, Sn and percent (%) solids.
>
> **Task 2.2: Ribbed Mussels and Co-Located Sediment Samples** Five composite samples of ribbed mussels and five co-located sediment samples will be collected. The mussels will be kept alive and brought back to the REAC Biology Laboratory for a depuration period up to 24 hours. Following the depuration period, the mussels will be frozen and then homogenized for tissue analyses. All samples will be analyzed for TAL metals, Sn and % solids.
>
> **Task 2.3: Green Algae (*Ulva*):** Five composite samples of green algae (Sea Lettuce, *Ulva*) will be collected within proximity of the jetties and seawall. The algae will be frozen on dry ice in the field and then homogenized for tissue analyses at the REAC Biology Laboratory. Samples will be analyzed for TAL metals, Sn and % solids.
>
> **Task 2.4: Foraging Fish.** Five composite samples of foraging fish (most likely killifish [*Fundulus*]) will be collected using a seine net within proximity of the jetties and seawall. The fish will be frozen on dry ice in the field and then homogenized for tissue analyses at the REAC Biological Laboratory. Samples will be analyzed for TAL metals, Sn and % solids.
>
> **Task 2.5: Clams and Co-Located Sediments.** The area immediately offshore of the beachfront will be surveyed for clams. If found five composite samples of clams and five co-located sediment samples will be collected. The clams will be kept alive and brought back to the REAC Biological Laboratory for a depuration period up to 24 hours. Following the depuration period, the clams will be frozen and then homogenized for tissue analyses. All samples will be analyzed for TAL metals, Sn and % solids.
>
> **Task 2.6: Waste Materials.** A total of 12 to 15 waste material samples will be collected at the jetties and the seawall by scraping or chiseling material from the surface areas and interior areas of these structures. All samples will be subjected to metal speciation analyses using x-ray diffraction (XRD) and x-ray fluorescence (XRF). In addition, the solubility of COCs will be assessed via a weak salt extraction procedure. At least three waste samples will be subjected to the TCLP procedure modified to assess leaching/extraction of COCs by seawater.

Task 2.7: Pore Water. Five pore water samples will be collected from sediments within the contaminated areas. An 8 inch sleeve will be inserted into the sediments and the two ends of the sleave will be capped off. Samples will be transported back to REAC Laboratory for extracting the pore water from the sediments. An aliquot of each sample will be filtered. The pore water samples (unfiltered and filtered) will be preserved with acid to pH of less than 2 .All samples will be analyzed for TAL metals and Sn.

Task 2.8: Mapping. A site map using Global Positioning System (GPS) equipment will depict site features and sample locations.

Task 3: Trip Report and Data Summaries. A draft field sampling trip report will be produced two weeks after completion of all field sampling activities. REAC scientists will provide a data summary of all analytical results, GPS data and other pertinent site features. Data will be validated by the REAC Data Validation and Report Writing (DVRG) Group.

Task 4: Draft Summary Report. A draft summary report will be provided in electronic format that will include summary and synthesis of all data and an interpretation of the data in an ERA format.

Task 5: Final Report. The final report will include a summary of the draft reports and a final technical evaluation of the data generated along with all relevant information. In conformance with the requirements of the REAC contract, all deliverables and other relevant project information will be submitted in electronic format to the appropriate ERT- Information Management System (IMS) website. All environmental sampling results will be provided as an electronic data deliverable (EDD) compatible with SCRIBE. Submission of the deliverables to the ERT-IMS website will be considered delivery to the EPA/ERT as of the date and time such deliverables are received on the website.

Quality Assurance Project Plan. Project management, measurement, assessment and usability elements applicable to this WA are included in the site-specific Quality Assurance Project Plan (QAPP).

Standard Operating Procedures. Any procedural standard operating procedures (SOPs) relevant to this QAPP are included in the site-specific QAPP. SOPs and Administrative Procedures (APs) relevant to this WA are included in the project-specific QAPP. REAC personnel will adhere to the following health and safety SOPs for this WA:

- SOP #3001, *REAC Health and Safety Program Policy and Implementation*
- SOP #3012, *REAC Health and Safety Guidelines for Activities at Hazardous Waste Sites*
- SOP #3020, *Inclement Weather, Heat Stress and Cold Stress*

STAFFING PLAN AND SCHEDULE

Staffing Plan. The REAC TL will maintain contact with the WAM to provide information on the technical and financial progress of the project. This communication will commence with the issuance of the WA. Activities will be summarized in appropriate format for inclusion in REAC Monthly Reports.

The WA for this project was received on August 6, 2008. The WP was initiated within 30 days after receiving the WA. The project will be completed by May 31, 2009.

The REAC TL/Quality Control (QC) Coordinator is the primary REAC point of contact with the WAM. The TL is responsible for the development and completion of the WP and QAPP, project team organization, and supervision of all project tasks, including reports and deliverables. In addition, the TL is responsible for ensuring adherence to, and recording any deviations from the WP or QAPP.

The REAC Quality Assurance Officer (QAO), Health and Safety Officer, Analytical Section Leader and Program Manager are responsible for auditing and guiding the project team, reviewing/auditing the deliverables and proposing corrective action, if necessary, for nonconformity to the WP and QAPP.

The following REAC personnel will work on this project:

Personnel	Responsibilities	Level of Responsibility
Task Leader	TL, Field Sampling, Report Preparation	P3
Environmental Technician	Field Sampling and Tissue Sample Processing	T3
Biology Group Leader	Document Review	P4
QA/QC Chemists	Data Validation and Report Writing	P3, P4
QAO	WP and QAPP Review/Validation Oversight	P4
Administrative Support	Document Archival	T3
Analytical Chemist	Analytical Subcontracting	P3

Additional REAC technical and/or administrative personnel and subcontractors may work on this project as needed.

Schedule of Activities. The anticipated schedule of activities is as follows:

WP	August 25, 2008
QAPP	September 5, 2008
Field Activities	Week of September 8, 2008
Processing Tissue Samples	Week of September 15, 2008
Trip Report	Two weeks following completion of field work
Draft Summary Report	Two weeks after receipt of validated data
Final Report	Two weeks following review of draft summary report

All project deliverable and task dates are estimates based on the information available at the time of WP completion. New information, additional tasks and events outside REAC control may result in revisions to these dates.

Training and Conference/Meeting/Seminar Attendance. In the course of performing the above tasks, REAC personnel may attend training offered by the EPA such as safety training, training for procedural changes made by the EPA, or training offered by outside vendors of specific equipment or instrumentation. Specific training instruction will be authorized in advance by the Project Officer and approved by the Contracting Officer. As authorized by the Project Officer and approved by the Contracting Officer, REAC personnel may attend a technical conference, meeting, or seminar to perform or support WA activities. For the ERT to successfully fulfill their mission to share and disseminate scientific information, REAC personnel will provide technical support to prepare (and present as necessary) technical papers/posters at scientific meetings or conferences.

LEVEL OF EFFORT AND COST PROJECTION

The estimated costs to complete this project are presented in the attached cost summary sheet. The estimated costs are based on the anticipated level of effort (LOE) hours for field work, sample preparation and report preparation and costs associated with similar projects. Activities such as electronic technical data documentation, photo documentation, computer graphics and support, report preparation, and purchasing support may also be required to accomplish project objectives. Labor hours for these activities have been included in the cost estimate. Estimated costs will be closely monitored particularly for the travel and analytical testing as follows:

Travel Assumptions are as follows:

Number of trips from Edison NJ to the Site	3
Number of personnel per trip	2
Number of days per trip	3

Vendor Services. Outside laboratories will be contracted for analytical testing at an approximate cost of $8,000.00. Ohio State University will conduct XRF and XRD determinations for 15 samples plus solubility tests for 6 samples at an approximate cost of $2,000.00. An outside laboratory will be selected to provide TAL metals and Sn analyses for 10 pore water samples, 15 sediment samples and 25 tissue samples and conduct modified TCLP-metals extraction and analyses for six samples at an approximate cost of $6,000.00.

ANALYTICAL REPORT

Prepared by
LOCKHEED MARTIN, Inc.

Laurence Harbor Site
Laurence Harbor, NJ

November 2008

EPA Work Assignment No. 0-356
LOCKHEED MARTIN Work Order EAC000356
EPA Contract No. EP-C-04-032

Submitted to
M. Sprenger
EPA-ERT

Dennis Killeen for	11/3/08	
V. Kansal Analytical Section Leader	Date	Analysis by: Katahdin
Dennis Killeen	11/3/08	
D. Killeen Quality Assurance Officer	Date	Prepared by: Y. Mehra
Dennis Miller	11/3/08	
D. Miller Program Manager	Date	Reviewed by: J. Soroka

0356-DAR-110308

Table of Contents

Appendices will be furnished on request.

Introduction

REAC, in response to WA# 0-356, provided analytical support for environmental samples collected from the Laurence Harbor Site in Laurence Harbor, New Jersey, as described in the following table. The support also included QA/QC, data review, and preparation of an analytical report containing the results and the QA/QC results.

Chain of Custody #	Number of Samples	Sampling Date	Date Received	Matrix	Analysis / Method	Lab	Data Package
356-09/15/08-0003	6	09/10/08	9/19/08	Tissue	TAL Metals/ SW-846 6020	Katahdin	T 304
356-09/15/08-0004	5						
356-09/15/08-0005	3	09/11/08					
356-09/15/08-0006	5	09/10/08					
356-09/15/08-0007	5						
356-09/24/08-0009	12	09/11/08	09/25/08	Sediment			T 308
	10	09/22/08		Pore Water			

[1] Katahdin is NELAC certified for Metals analysis.

Case Narrative

The metals data are reported to two significant figures and reported as received from the laboratory. Any other representation of the data is the responsibility of the user. All data validation flags have been inserted into the results tables.

Due to the high levels of acid used during the digestion procedure for ICP-MS metals, all samples underwent a five-fold dilution before analysis. All RLs have been adjusted for dilution.

Metals in Tissue Package T 304

Manganese and copper were detected in the continuing calibration blank (CCB) of 10/2/08-23:44 above the RL. Manganese and copper are qualified estimated high (J+) for the method blank of 10/2/08 and the CO_2 blank.

Copper and lead were detected in the method blank 10/1/08 above the RL. Copper and lead are qualified estimated high (J+) for samples 356-0037 through -0041.

Barium, copper, manganese and nickel were detected in the CO_2 blank above the RL. Barium, copper, manganese and nickel are qualified estimated high (J+) for samples 356-0023, -0024, -0026, -0027, -0028 and -0029. Barium, manganese and nickel are qualified estimated high (J+) for sample 356-0025. Barium and nickel are qualified estimated high (J+) for samples 356-0030, -0031, -0032, -0033, -0034, -0035, and -0036. Barium, copper and nickel are qualified estimated high (J+) for samples 356-0037, -0038, -0039, -0040, -0041, -0042, -0043, -0044, -0045 and -0046.

Aluminum did not meet the %D criterion for the serial dilution analysis of sample 356-0023. Aluminum is qualified estimated (J) for samples 356-0023 through -0041.

Aluminum and manganese did not meet the % recovery criterion for the MS/MSD of sample 356-0043.

Aluminum is qualified estimated high (J+) and manganese estimated low (J-) for samples 356-0042 through -0046.

Metals in Sediment and Water Package T 308

The sediment blank (356-0022) contained aluminum, barium, chromium, copper, lead, manganese and nickel above the reporting limit. Barium is qualified estimated high (J+) for samples 356-0011, -0012, -0013, -0017, -0018 and -0021. Copper is qualified estimated high (J+) for samples 356-0011, -0012, -0020 and -0021. Manganese is qualified estimated high (J+) for samples 356-0011, -0014, -0017, -0019 and -0021. Nickel is qualified estimated high (J+) for samples 356-0011 and -0014.

Manganese and tin did not meet the %RPD criterion for the MS/MSD analysis of sample 356-0011. Manganese did not meet the % recovery criterion for the MS and tin did not meet the % recovery criterion for the MSD of sample 356-0011. Manganese and tin are qualified estimated (J) for samples 356-0011 through -0022.

Arsenic did not meet the %D criterion for the serial dilution analysis of sample 356-0011. Arsenic is qualified estimated (J) for sample 356-0011 through 356-0022.

Summary of Abbreviations

BFB	Bromofluorobenzene
C	Centigrade
CLP	Contract Laboratory Program
COC	Chain of Custody
conc	concentration
cont	continued
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
D	(Surrogate Table) value is from a diluted sample and was not calculated
Dioxin	Polychlorinated dibenzo-p-dioxins (PCDD) and Polychlorinated dibenzofurans (PCDF)
DFTPP	Decafluorotriphenylphosphine
EMPC	Estimated maximum possible concentration
GC/MS	Gas Chromatography/ Mass Spectrometry
IS	Internal Standard
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MDA	Minimum Detectable Activity
MS (BS)	Matrix Spike (Blank Spike)
MSD (BSD)	Matrix Spike Duplicate (Blank Spike Duplicate)
MW	Molecular Weight
NA	Not Applicable or Not Available
NAD	Normalized Absolute Difference
NC	Not Calculated
NR	Not Requested/Not Reported
NS	Not Spiked
% D	Percent Difference
% REC	Percent Recovery
SOP	Standard Operating Procedure
ppbv	parts per billion by volume
ppm	parts per million
pptv	parts per trillion by volume
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
QL	Quantitation Limit
REAC	Response Engineering and Analytical Contract
RL	Reporting Limit
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SIM	Selected Ion Monitoring
Sur	Surrogate
TIC	Tentatively Identified Compound
TCLP	Toxicity Characteristic Leaching Procedure
VOC	Volatile Organic Compound
*	Value exceeds the acceptable QC limits.

m^3	cubic meter	g	gram	kg	kilogram	L	liter
µg	microgram	µL	microliter	mg	milligram	mL	milliliter
ng	nanogram	pg	picogram	pCi	picocurie	s	sigma

Data Validation Flags

J	Value is estimated	R	Value is unusable
J+	Value is estimated high (metals only)	U	Not detected
J-	Value is estimated low (metals only)	UJ	Not detected and RL is estimated

Rev. 02/05/08

Table 1.1 Results of the Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	10/1/2008	356-0023	356-0024	356-0025	356-0026
Sample Location	Method Blank	RM-1	RM-2	RM-3	RM-4
Percent Solids	--	8.7	9.0	13	8.6

Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	U	30	U J	70	U J	62	48 J	42	U J	64
Antimony	U	0.10	U	0.23	0.24	0.21	0.23	0.14	U	0.21
Arsenic	U	0.50	7.7	1.2	7.6	1.0	6.1	0.69	7.7	1.1
Barium	U	0.10	0.60 J+	0.23	0.66 J+	0.21	0.46 J+	0.14	0.48 J+	0.21
Beryllium	U	0.10	U	0.23	U	0.21	U	0.14	U	0.21
Cadmium	U	0.10	0.83	0.23	0.94	0.21	0.48	0.14	0.74	0.21
Chromium	U	0.30	2.3	0.70	2.0	0.62	1.8	0.42	2.1	0.64
Cobalt	U	0.10	0.28	0.23	0.31	0.21	0.22	0.14	0.31	0.21
Copper	0.63	0.10	14 J+	0.23	16 J+	0.21	10	0.14	14 J+	0.21
Lead	0.12	0.10	3.0	0.23	5.1	0.21	3.3	0.14	4.0	0.21
Manganese	U	0.10	5.3 J+	0.23	4.7 J+	0.21	4.4 J+	0.14	6.3 J+	0.21
Nickel	U	0.10	0.54 J+	0.23	0.63 J+	0.21	0.57 J+	0.14	0.62 J+	0.21
Selenium	U	0.50	2.6	1.2	2.4	1.0	1.4	0.69	2.4	1.1
Silver	U	0.10	0.76	0.23	0.71	0.21	0.38	0.14	0.52	0.21
Thallium	U	0.20	U	0.46	U	0.41	U	0.28	U	0.43
Tin	U	10	U	23	U	21	U	14	U	21
Vanadium	U	0.50	U	1.2	1.8	1.0	1.2	0.69	U	1.1
Zinc	U	1.0	57	2.3	64	2.1	41	1.4	57	2.1

Table 1.1 (cont) Results of the Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	356-0027	356-0028	356-0029	356-0030	356-0031
Sample Location	RM-5	RM-6	Mya-1	Mya-2	Mya-3
Percent Solids	10	9.4	12	13	12

Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	U J	58	U J	62	U J	45	230 J	81	220 J	48
Antimony	U	0.19	0.25	0.21	U	0.15	0.40	0.27	0.37	0.16
Arsenic	7.7	0.96	9.5	1	1.4	0.75	7.6	1.4	6.4	0.8
Barium	0.41 J+	0.19	0.50 J+	0.21	0.75 J+	0.15	3.8 J+	0.27	2.9 J+	0.16
Beryllium	U	0.19	U	0.21	U	0.15	U	0.27	U	0.16
Cadmium	0.58	0.19	0.40	0.21	U	0.15	U	0.27	0.33	0.16
Chromium	1.3	0.58	1.6	0.62	0.67	0.45	1.6	0.81	1.6	0.48
Cobalt	0.28	0.19	0.29	0.21	U	0.15	0.44	0.27	1.0	0.16
Copper	12 J+	0.19	14 J+	0.21	8.5 J+	0.15	21	0.27	22	0.16
Lead	6.0	0.19	8.6	0.21	3.4	0.15	15	0.27	17	0.16
Manganese	5.0 J+	0.19	7.1 J+	0.21	4.3 J+	0.15	30	0.27	130	0.16
Nickel	0.45 J+	0.19	0.54 J+	0.21	0.36 J+	0.15	1.3 J+	0.27	1.3 J+	0.16
Selenium	2.5	0.96	2.6	1	U	0.75	2.3	1.4	1.6	0.80
Silver	0.48	0.19	0.38	0.21	U	0.15	0.38	0.27	0.70	0.16
Thallium	U	0.38	U	0.42	U	0.3	U	0.54	U	0.32
Tin	U	19	U	21	U	15	U	27	U	16
Vanadium	U	0.96	1.1	1	U	0.75	2.4	1.4	2.7	0.80
Zinc	53	1.9	59	2.1	21	1.5	94	2.7	96	1.6

Table 1.1 (cont) Results of the Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	356-0032		356-0033		356-0034		356-0035		356-0036	
Sample Location	Mya-4		Mya-5		Mer-1		Mer-2		Mer-3	
Percent Solids	15		13		17		17		16	
Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	200 J	36	190 J	40	U J	34	U J	32	U J	31
Antimony	1.2	0.12	0.33	0.13	U	0.11	U	0.11	U	0.10
Arsenic	7.3	0.59	7.2	0.66	5.1	0.57	5.9	0.53	9.8	0.52
Barium	3.3 J+	0.12	3.3 J	0.13	0.66 J+	0.11	0.66 J+	0.11	0.71 J+	0.10
Beryllium	U	0.12	U	0.13	U	0.11	U	0.11	U	0.10
Cadmium	0.14	0.12	0.14	0.13	0.82	0.11	1.0	0.11	0.96	0.10
Chromium	3.1	0.36	1.5	0.40	1.8	0.34	1.6	0.32	1.2	0.31
Cobalt	0.41	0.12	0.44	0.13	0.34	0.11	0.33	0.11	0.79	0.10
Copper	31	0.12	24	0.13	14	0.11	11	0.11	14.3	0.10
Lead	16	0.12	14	0.13	1.7	0.11	2.9	0.11	3.1	0.10
Manganese	20	0.12	21	0.13	52	0.11	200	0.11	120	0.10
Nickel	1.4 J+	0.12	1.7 J+	0.13	1.4 J+	0.11	0.95 J+	0.11	1.6 J+	0.10
Selenium	2.0	0.59	2.3	0.66	0.97	0.57	1.3	0.53	1.4	0.52
Silver	0.50	0.12	0.52	0.13	0.19	0.11	0.26	0.11	2.1	0.10
Thallium	U	0.24	U	0.26	U	0.23	U	0.21	U	0.21
Tin	U	12	U	13	U	11	U	11	U	10
Vanadium	2.0	0.59	1.9	0.66	U	0.57	U	0.53	0.55	0.52
Zinc	86	1.2	94	1.3	69	1.1	93	1.1	120	1.0

Table 1.1 (cont) Results of the Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	356-0037		356-0038		356-0039		356-0040		356-0041	
Sample Location	FF-1		FF-2		FF-3		FF-4		FF-5	
Percent Solids	26		26		27		26		25	
Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	U J	52	U J	57	U J	48	U J	50	U J	87
Antimony	U	0.17	U	0.19	U	0.16	U	0.17	U	0.29
Arsenic	3.6	0.86	3.5	0.95	3.5	0.80	3.8	0.84	3.7	1.4
Barium	5.1 J+	0.17	5.9 J+	0.19	3.2 J+	0.16	5.7 J+	0.17	4.7 J+	0.29
Beryllium	U	0.17	U	0.19	U	0.16	U	0.17	U	0.29
Cadmium	U	0.17	U	0.19	U	0.16	U	0.17	U	0.29
Chromium	1.0	0.52	1.0	0.57	0.98	0.48	1.1	0.50	1.3	0.87
Cobalt	U	0.17	U	0.19	U	0.16	U	0.17	U	0.29
Copper	5.0 J+	0.17	4.8 J+	0.19	5.9 J+	0.16	6.1 J+	0.17	5.0 J+	0.29
Lead	0.52 J+	0.17	0.92 J+	0.19	0.49 J+	0.16	0.49 J+	0.17	0.52 J+	0.29
Manganese	13	0.17	18	0.19	14	0.16	17	0.17	15	0.29
Nickel	0.34 J+	0.17	0.39 J+	0.19	0.33 J+	0.16	0.39 J+	0.17	0.38 J+	0.29
Selenium	1.8	0.86	2.0	0.95	1.8	0.80	2.1	0.84	1.8	1.4
Silver	U	0.17	U	0.19	U	0.16	U	0.17	U	0.29
Thallium	U	0.34	U	0.38	U	0.32	U	0.34	U	0.58
Tin	U	17	U	19	U	16	U	17	U	29
Vanadium	1.1	0.86	1.2	0.95	0.88	0.8	1.1	0.84	U	1.4
Zinc	80	1.7	93	1.9	79	1.6	93	1.7	87	2.9

Table 1.1 (cont) Results of the Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	10/2/2008		356-0042		356-0043		356-0044		356-0045	
Sample Location	Method Blank		Ulva-1		Ulva-2		Ulva-3		Ulva-4	
Percent Solids	--		19		18		16		18	
Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	U	30	680 J+	56	480 J+	69	610 J+	55	740 J+	60
Antimony	U	0.10	0.23	0.19	0.60	0.23	0.54	0.18	0.57	0.20
Arsenic	U	0.50	4.7	0.94	15	1.2	10	0.91	12	1.0
Barium	U	0.10	2.2 J+	0.19	5.2 J+	0.23	4.1 J+	0.18	4.3 J+	0.20
Beryllium	U	0.10	U	0.19	U	0.23	U	0.18	U	0.20
Cadmium	U	0.10	U	0.19	U	0.23	U	0.18	U	0.20
Chromium	U	0.30	5.0	0.56	2.6	0.69	2.8	0.55	4.6	0.60
Cobalt	U	0.10	0.73	0.19	0.97	0.23	1.1	0.18	1.2	0.20
Copper	0.76 J+	0.10	12 J+	0.19	9.7 J+	0.23	11 J+	0.18	12 J+	0.20
Lead	U	0.10	24	0.19	56	0.23	66	0.18	69	0.20
Manganese	0.11 J+	0.10	120 J-	0.19	230 J-	0.23	250 J-	0.18	280 J-	0.20
Nickel	U	0.10	2.6 J+	0.19	4.0 J+	0.23	4.7 J+	0.18	3.4 J+	0.20
Selenium	U	0.50	U	0.94	U	1.2	U	0.91	U	1.0
Silver	U	0.10	U	0.19	U	0.23	U	0.18	U	0.20
Thallium	U	0.20	U	0.38	U	0.46	U	0.36	U	0.40
Tin	U	10	U	19	U	23	U	18	U	20
Vanadium	U	0.50	12	0.94	20	1.2	13	0.91	23	1.0
Zinc	U	1.0	32	1.9	51	2.3	41	1.8	51	2.0

Table 1.1 (cont) Results of the Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	356-0046		9/29/2008		CO2 BLANK	
Sample Location	Ulva-5		Method Blank		CO2 BLANK	
Percent Solids	17		--		--	
Analyte	Result mg/Kg	RL mg/Kg	Result ug/L	RL ug/L	Result ug/L	RL ug/L
Aluminum	770 J+	62	U	300	U	300
Antimony	0.75	0.21	U	1.0	U	1.0
Arsenic	6.3	1.0	U	5.0	U	5.0
Barium	3.0 J+	0.21	U	1.0	1.7	1.0
Beryllium	U	0.21	U	1.0	U	1.0
Cadmium	U	0.21	U	1.0	U	1.0
Chromium	3.4	0.62	U	3.0	U	3.0
Cobalt	1.2	0.21	U	1.0	U	1.0
Copper	13 J+	0.21	U	1.0	2.0 J+	1.0
Lead	80	0.21	U	1.0	U	1.0
Manganese	280 J-	0.21	U	1.0	1.3 J+	1.0
Nickel	3.6 J+	0.21	U	1.0	1.2	1.0
Selenium	U	1.0	U	5.0	U	5.0
Silver	U	0.21	U	1.0	U	1.0
Thallium	U	0.41	U	2.0	U	2.0
Tin	U	21	U	100	U	100
Vanadium	7.4	1.0	U	5.0	U	5.0
Zinc	38	2.1	U	10	U	10

Table 1.2 Result of the Analysis for Metals in Sediment
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	9/30/2008		356-0011		356-0012		356-0013		356-0014	
Sample Location	Method Blank		SS-RM1		SS-RM2		SS-RM3		SS-RM4	
Percent Solids	--		78		78		80		72	
Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	U	30	1400	33	1000	28	1500	27	1300	23
Antimony	U	0.10	0.22	0.11	0.31	0.095	0.49	0.089	1.5	0.077
Arsenic	U	0.50	5.6 J	0.56	6.1 J	0.47	8.5 J	0.44	6.9 J	0.38
Barium	U	0.10	2.8 J+	0.11	1.7 J+	0.095	2.4 J+	0.089	6.8	0.077
Beryllium	U	0.10	0.14	0.11	0.18	0.095	0.31	0.089	0.16	0.077
Cadmium	U	0.10	0.14	0.11	U	0.095	0.22	0.089	0.13	0.077
Chromium	U	0.30	9.0	0.33	9.5	0.28	21	0.27	7.7	0.23
Cobalt	U	0.10	0.60	0.11	1.5	0.095	0.92	0.089	0.93	0.077
Copper	U	1.0	4.4 J+	1.1	9.9 J+	0.95	15	0.89	11	0.77
Lead	U	0.10	12	0.11	16	0.095	19	0.089	94	0.077
Manganese	0.11	0.10	22 J	0.11	44 J	0.095	48 J	0.089	28 J	0.077
Nickel	U	0.10	1.6 J+	0.11	3.0	0.095	2.6	0.089	2.3 J+	0.077
Selenium	U	0.50	U	0.56	U	0.47	U	0.44	U	0.38
Silver	U	0.10	U	0.11	U	0.095	U	0.089	0.080	0.077
Thallium	U	0.20	U	0.22	U	0.19	U	0.18	U	0.15
Tin	U	10	U J	11	U J	9.5	U J	8.9	8.0 J	7.7
Vanadium	U	0.50	26	0.56	21	0.47	38	0.44	17	0.38
Zinc	U	1.0	25	1.1	31	0.95	33	0.89	40	0.77

Table 1.2 (cont) Result of the Analysis for Metals in Sediment
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	356-0015		356-0016		356-0017		356-0018		356-0019	
Sample Location	SS-RM5		SS-RM6		SS-MM1		SS-MM2		SS-MM3	
Percent Solids	72		79		71		77		67	
Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	2900	62	4200	30	1600	26	3000	30	2700	41
Antimony	6.1	0.10	1.6	0.099	1.1	0.087	0.84	0.10	1.2	0.14
Arsenic	13 J	0.51	29 J	0.50	9.4 J	0.43	15 J	0.50	5.4 J	0.68
Barium	8.9	0.10	5.5	0.099	4.3 J+	0.087	4.0 J+	0.10	5.5	0.14
Beryllium	0.29	0.10	0.66	0.099	0.25	0.087	0.74	0.10	0.22	0.14
Cadmium	U	0.10	0.33	0.099	0.34	0.087	0.15	0.10	0.42	0.14
Chromium	18	0.31	46	0.30	15	0.26	37	0.30	14	0.41
Cobalt	2.3	0.10	3.8	0.099	1.5	0.087	1.9	0.10	0.78	0.14
Copper	22	1.0	17	0.99	13	0.87	11	1.0	31	1.4
Lead	660	0.20	93	0.099	47	0.087	29	0.10	83	0.14
Manganese	260 J	0.10	99 J	0.099	29 J	0.087	56 J	0.10	19 J	0.14
Nickel	5.8	0.10	8.5	0.099	5.0	0.087	6.6	0.10	2.9	0.14
Selenium	U	0.51	U	0.50	U	0.43	U	0.50	U	0.68
Silver	0.19	0.10	0.12	0.099	0.13	0.087	U	0.10	1.1	0.14
Thallium	U	0.20	U	0.20	U	0.17	U	0.20	U	0.27
Tin	18 J	10	U J	9.9	8.7 J	8.7	U J	10	U J	14
Vanadium	29	0.51	76	0.50	29	0.43	84	0.50	36	0.68
Zinc	57	1.0	91	0.99	68	0.87	91	1.0	53	1.4

Table 1.2 (cont) Result of the Analysis for Metals in Sediment
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Method : SW846 6020

Sample Number	356-0020	356-0021	356-0022
Sample Location	SS-MM4	SS-MM5	Sediment Blank
Percent Solids	69	71	100

Analyte	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg	Result mg/Kg	RL mg/Kg
Aluminum	3000	30	2000	26	86	28
Antimony	0.42	0.099	0.47	0.087	U	0.093
Arsenic	12 J	0.50	7.4 J	0.44	U J	0.46
Barium	5.0	0.099	3.4 J+	0.087	0.44	0.093
Beryllium	0.46	0.099	0.33	0.087	U	0.093
Cadmium	0.17	0.099	0.13	0.087	U	0.093
Chromium	44	0.30	11	0.26	0.61	0.28
Cobalt	1.7	0.099	1.2	0.087	U	0.093
Copper	9.4 J+	0.99	7.4 J+	0.87	1.0	0.93
Lead	26	0.099	24	0.087	0.26	0.093
Manganese	55 J	0.099	32 J	0.087	3.8 J	0.093
Nickel	4.9	0.099	2.8	0.087	0.26	0.093
Selenium	U	0.50	U	0.44	U	0.46
Silver	U	0.099	U	0.087	U	0.093
Thallium	U	0.20	U	0.17	U	0.18
Tin	U J	9.9	U J	8.7	U J	9.3
Vanadium	73	0.50	28	0.44	U	0.46
Zinc	56	0.99	44	0.87	U	0.93

Table 1.3 Result of the Analysis for Metals in Water
WA # 356 Laurence Harbor Site

Method : SW846 6020

Sample Number	9/29/2008		356-0047		356-0053		356-0054		356-0055	
Sample Location	Method Blank		PW-A1 (Total/Unfiltered)		PW-A2 (Filtered)		PW-B1 (Total/Unfiltered)		PW-B2 (Filtered)	
Analyte	Result ug/L	RL ug/L	Result ug/L	RL ug/L	Result ug/L	RL ug/L	Result ug/L	RL ug/L	Result ug/L	RL ug/L
Aluminum	U	300	U	1200	U	600	U	600	U	600
Antimony	U	1.0	U	4.0	U	2.0	U	2.0	U	2.0
Arsenic	U	5.0	U	20	11	10	19	10	23	10
Barium	U	1.0	46	4.0	43	2.0	25	2.0	24	2.0
Beryllium	U	1.0	U	8.0	U	4.0	U	4.0	U	2.0
Cadmium	U	1.0	U	4.0	U	2.0	U	2.0	U	2.0
Chromium	U	3.0	U	12	U	6.0	7.6	6.0	6.6	6.0
Cobalt	U	1.0	U	4.0	U	2.0	U	2.0	U	2.0
Copper	U	10	U	80	U	40	U	40	U	20
Lead	U	1.0	U	8.0	U	4.0	10	4.0	U	2.0
Manganese	U	1.0	810	4.0	840	2.0	540	2.0	530	2.0
Nickel	U	1.0	9.6	4.0	7.3	2.0	6.9	2.0	4.9	2.0
Selenium	U	5.0	U	40	U	25	U	20	U	10
Silver	U	1.0	U	4.0	U	2.0	U	2.0	U	2.0
Thallium	U	2.0	U	8.0	U	4.0	U	4.0	U	4.0
Tin	U	100	U	400	U	200	U	200	U	200
Vanadium	U	5.0	U	20	U	10	U	10	U	10
Zinc	U	10	U	40	U	20	U	20	U	20

Table 1.3 (cont) Result of the Analysis for Metals in Water
WA # 356 Laurence Harbor Site

Method : SW846 6020

Sample Number	356-0056		356-0057		356-0058		356-0059		356-0060	
Sample Location	PW-C1 (Total/Unfiltered)		PW-C2 (Filtered)		PW-D1 (Total/Unfiltered)		PW-D2 (Filtered)		PW-E1 (Total/Unfiltered)	
Analyte	Result ug/L	RL ug/L	Result ug/L	RL ug/L	Result ug/L	RL ug/L	Result ug/L	RL ug/L	Result ug/L	RL ug/L
Aluminum	U	600	U	600	1900	600	U	600	U	600
Antimony	56	2.0	19	2.0	270	2.0	130	2.0	9.7	2.0
Arsenic	71	10	41	10	230	10	86	10	39	10
Barium	39	2.0	35	2.0	47	2.0	34	2.0	26	2.0
Beryllium	U	2.0	U	2.0	U	2.0	U	2.0	U	2.0
Cadmium	U	2.0	U	2.0	U	2.0	U	2.0	U	2.0
Chromium	9.8	6.0	6.6	6.0	17	6.0	7.1	6.0	7.9	6.0
Cobalt	3.2	2.0	2.0	2.0	7.4	2.0	U	2.0	3.3	2.0
Copper	U	40	U	20	91	40	U	40	U	40
Lead	1500	4.0	U	2.0	2400	4.0	170	4.0	160	4.0
Manganese	1800	2.0	1800	2.0	1300	2.0	1100	2.0	2300	2.0
Nickel	10	2.0	6.1	2.0	33	2.0	11	2.0	5.8	2.0
Selenium	U	25	U	10	U	50	U	10	U	20
Silver	U	2.0	U	2.0	U	2.0	U	2.0	U	2.0
Thallium	U	4.0	U	4.0	U	4.0	U	4.0	U	4.0
Tin	U	200	U	200	U	200	U	200	U	200
Vanadium	11	10	U	10	21	10	12	10	U	10
Zinc	27	20	U	20	150	20	U	20	U	20

Table 1.3 (cont) Result of the Analysis for Metals in Water
WA # 356 Laurence Harbor Site

Method : SW846 6020

Sample Number 356-0061
Sample Location PW-E2 (Filtered)

Analyte	Result ug/L	RL ug/L
Aluminum	U	600
Antimony	4.0	2.0
Arsenic	29	10
Barium	25	2.0
Beryllium	U	2.0
Cadmium	U	2.0
Chromium	6.4	6.0
Cobalt	3.1	2.0
Copper	U	20
Lead	U	2.0
Manganese	2200	2.0
Nickel	5.5	2.0
Selenium	U	10
Silver	U	2.0
Thallium	U	4.0
Tin	U	200
Vanadium	U	10
Zinc	U	20

Table 2.1 Results of the MS/MSD Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Sample Number: 356-0023

Analyte	Sample Conc mg/kg	MS Spike Added mg/kg	MS Conc mg/kg	MS % Recovery		MSD Spike Added mg/kg	MSD Conc mg/kg	MSD % Recovery		RPD	QC Limits % Recovery	QC Limits RPD
Aluminum	44	460	480	95		440	480	99		2	75.0-125	20
Antimony	0.14	120	100	88		110	96	88		5	75.0-125	20
Arsenic	7.7	120	110	90		110	100	88		7	75.0-125	20
Barium	0.60	460	420	91		440	380	87		10	75.0-125	20
Beryllium	U	12	10	89		11	10	91		3	75.0-125	20
Cadmium	0.83	58	53	90		55	49	88		8	75.0-125	20
Chromium	2.3	46	44	89		44	40	87		8	75.0-125	20
Cobalt	0.28	120	100	90		110	98	89		7	75.0-125	20
Copper	14	58	67	91		55	62	87		8	75.0-125	20
Lead	3.0	120	110	90		110	100	89		6	75.0-125	20
Manganese	5.3	120	110	89		110	100	87		8	75.0-125	20
Nickel	0.54	120	104	89		110	98	89		6	75.0-125	20
Selenium	2.6	120	110	89		110	97	87		8	75.0-125	20
Silver	0.76	12	11	89		11	10	85		9	75.0-125	20
Thallium	U	120	100	88		110	94	86		7	75.0-125	20
Tin	7.3	120	110	87		110	100	87		5	75.0-125	20
Vanadium	0.79	120	110	91		110	99	89		8	75.0-125	20
Zinc	57	120	160	87		110	150	84		6	75.0-125	20

Sample Number: 356-0043

Analyte	Sample Conc mg/kg	MS Spike Added mg/kg	MS Conc mg/kg	MS % Recovery		MSD Spike Added mg/kg	MSD Conc mg/kg	MSD % Recovery		RPD	QC Limits % Recovery	QC Limits RPD
Aluminum	480	470	1200	165	*	470	1300	177	*	5	75.0-125	20
Antimony	0.60	120	110	94		120	110	93		1	75.0-125	20
Arsenic	15	120	120	93		120	120	92		0	75.0-125	20
Barium	5.2	470	450	94		470	450	95		1	75.0-125	20
Beryllium	U	12	12	103		12	12	101		0	75.0-125	20
Cadmium	U	58	56	96		59	57	96		1	75.0-125	20
Chromium	2.6	47	46	92		47	45	90		1	75.0-125	20
Cobalt	0.97	120	110	93		120	110	92		0	75.0-125	20
Copper	9.7	58	69	101		59	72	105		5	75.0-125	20
Lead	56	120	160	88		120	160	89		2	75.0-125	20
Manganese	230	120	310	72	*	120	380	124		18	75.0-125	20
Nickel	4.0	120	110	94		120	110	92		0	75.0-125	20
Selenium	U	120	110	93		120	110	93		2	75.0-125	20
Silver	U	12	11	96		12	11	94		1	75.0-125	20
Thallium	U	120	110	92		120	110	92		1	75.0-125	20
Tin	U	120	120	107		120	120	105		0	75.0-125	20
Vanadium	20	120	130	91		120	130	90		0	75.0-125	20
Zinc	51	120	160	90		120	160	89		0	75.0-125	20

Table 2.2 Results of the MS/MSD Analysis for Metals in Sediment
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Sample Number: 356-0011

Analyte	Sample Conc mg/kg	MS Spike Added mg/kg	MS Conc mg/kg	MS % Recovery	MSD Spike Added mg/kg	MSD Conc mg/kg	MSD % Recovery	RPD	QC Limits % Recovery	QC Limits RPD
Aluminum	1400	220	2400	NC	220	2500	NC	4	75-125	20
Antimony	0.23	54	45	82	55	46	83	2	75-125	20
Arsenic	5.6	54	59	98	55	56	93	4	75-125	20
Barium	2.8	220	210	94	220	210	93	0	75-125	20
Beryllium	0.14	5.4	5.1	91	5.5	5.2	92	2	75-125	20
Cadmium	0.14	27	26	93	27	25	91	2	75-125	20
Chromium	9.0	22	34	115	22	33	109	4	75-125	20
Cobalt	0.60	54	53	97	55	54	97	1	75-125	20
Copper	4.4	27	30	94	27	30	94	1	75-125	20
Lead	12	54	72	110	55	61	90	16	75-125	20
Manganese	22	54	82	110	55	100	145 *	22 *	75-125	20
Nickel	1.6	54	54	97	55	55	98	2	75-125	20
Selenium	U	54	51	94	55	50	91	2	75-125	20
Silver	U	5.4	5.1	93	5.5	5.1	92	1	75-125	20
Thallium	U	54	52	96	55	51	93	2	75-125	20
Tin	U	54	73	128 *	55	58	99	24 *	75-125	20
Vanadium	26	54	84	107	55	72	85	15	75-125	20
Zinc	25	54	75	93	55	78	97	3	75-125	20

Table 2.3 Results of the MS Analysis for Metals in Water
WA # 356 Laurence Harbor Site

Sample Number: 356-0047

Analyte	Sample Conc µg/L	MS Spike Added µg/L	MS Conc µg/L	MS % Recovery	QC Limits % Recovery
Aluminum	U	2000	2400	106	75-125
Antimony	U	500	500	99	75-125
Arsenic	U	500	500	98	75-125
Barium	46	2000	1900	94	75-125
Beryllium	U	50	43	86	75-125
Cadmium	U	250	210	84	75-125
Chromium	U	200	190	92	75-125
Cobalt	U	500	450	89	75-125
Copper	U	250	230	90	75-125
Lead	U	500	490	97	75-125
Manganese	810	500	1200	80	75-125
Nickel	9.6	500	440	85	75-125
Selenium	U	500	430	86	75-125
Silver	U	50	42	83	75-125
Thallium	U	500	490	98	75-125
Tin	U	500	520	103	75-125
Vanadium	U	500	500	98	75-125
Zinc	U	500	430	81	75-125

Table 2.4 Results of the LCS Analysis for Metals in Tissue
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Date Analyzed 10/1/08

Analyte	LCS Spike Added mg/kg	LCS Conc mg/kg	% Recovery	QC Limits % Recovery
Aluminum	20	22	109	80-120
Antimony	5.0	4.7	95	80-120
Arsenic	5.0	4.8	95	80-120
Barium	20	19	95	80-120
Beryllium	0.5	0.45	90	80-120
Cadmium	2.5	2.4	95	80-120
Chromium	2.0	1.9	95	80-120
Cobalt	5.0	4.7	94	80-120
Copper	2.5	2.4	97	80-120
Lead	5.0	4.7	94	80-120
Manganese	5.0	4.6	92	80-120
Nickel	5.0	4.8	95	80-120
Selenium	5.0	4.7	94	80-120
Silver	0.5	0.48	96	80-120
Thallium	5.0	4.6	91	80-120
Tin	5.0	5.1	103	80-120
Vanadium	5.0	4.7	94	80-120
Zinc	5.0	4.8	96	80-120

Date Analyzed 10/2/08

Analyte	LCS Spike Added mg/kg	LCS Conc mg/kg	% Recovery	QC Limits % Recovery
Aluminum	20	21	105	80-120
Antimony	5.0	4.8	97	80-120
Arsenic	5.0	4.7	94	80-120
Barium	20	19	95	80-120
Beryllium	0.5	0.51	101	80-120
Cadmium	2.5	2.4	95	80-120
Chromium	2.0	1.8	92	80-120
Cobalt	5.0	4.6	93	80-120
Copper	2.5	2.4	96	80-120
Lead	5.0	4.7	94	80-120
Manganese	5.0	4.6	91	80-120
Nickel	5.0	4.6	93	80-120
Selenium	5.0	4.6	93	80-120
Silver	0.5	0.47	94	80-120
Thallium	5.0	4.6	92	80-120
Tin	5.0	5.3	107	80-120
Vanadium	5.0	4.6	91	80-120
Zinc	5.0	4.7	93	80-120

Table 2.5 Results of the LCS/LCSD Analysis for Metals in Water
WA # 356 Laurence Harbor Site

Date Analyzed 09/29/08

Analyte	LCS/LCSD Spike Added µg/L	LCS Conc. µg/L	LCS % Recovery	LCSD Conc. µg/L	LCSD % Recovery	%RPD	QC Limits % Recovery	QC Limits %RPD
Aluminum	2000	2200	108	2100	103	4	80-120	20
Antimony	500	530	106	500	100	6	80-120	20
Arsenic	500	520	104	490	98	6	80-120	20
Barium	2000	2000	101	1900	96	5	80-120	20
Beryllium	50	52	105	55	111	6	80-120	20
Cadmium	250	260	106	250	101	4	80-120	20
Chromium	200	190	96	190	93	3	80-120	20
Cobalt	500	490	97	470	94	3	80-120	20
Copper	250	250	100	240	96	4	80-120	20
Lead	500	510	101	480	97	4	80-120	20
Manganese	500	480	96	460	92	5	80-120	20
Nickel	500	490	98	470	94	4	80-120	20
Selenium	500	510	101	480	96	5	80-120	20
Silver	50	51	102	49	98	4	80-120	20
Thallium	500	480	97	470	95	3	80-120	20
Tin	500	560	112	530	106	6	80-120	20
Vanadium	500	470	95	460	92	3	80-120	20
Zinc	500	490	99	480	95	4	80-120	20

Table 2.6 Results of the LCS Analysis for Metals in Sediment
WA # 356 Laurence Harbor Site
Results are Based on Dry Weight

Date Analyzed 09/30/08

Analyte	LCS Spike Added mg/kg	LCS Conc mg/kg	% Recovery	QC Limits % Recovery
Aluminum	7900	9700	123	59-141
Antimony	71	52	74	0-211
Arsenic	290	270	93	81-119
Barium	210	200	95	82-117
Beryllium	54	51	93	83-117
Cadmium	100	93	93	82-118
Chromium	220	240	109	80-120
Cobalt	100	100	100	82-118
Copper	88	84	95	83-117
Lead	160	140	88	82-118
Manganese	420	420	100	82-118
Nickel	120	120	100	83-118
Selenium	130	120	92	78-122
Silver	100	100	100	66-134
Thallium	94	90	96	77-122
Tin	150	160	107	70-130
Vanadium	110	120	109	77-123
Zinc	270	260	96	79-121

Table 2.7 Results of the Duplicate Analysis for Metals in Water
WA # 356 Laurence Harbor Site

Sample Number: 356-0054

Analyte	Initial Analysis µg/L	Duplicate Analysis µg/L	RPD	QC Limits % RPD
Aluminum	U	U	NC	20
Antimony	U	U	NC	20
Arsenic	19	22	14	20
Barium	25	26	6	20
Beryllium	U	U	NC	20
Cadmium	U	U	NC	20
Chromium	7.6	8.2	8	20
Cobalt	U	U	NC	20
Copper	U	U	NC	20
Lead	10	10	1	20
Manganese	540	550	1	20
Nickel	6.9	6.7	3	20
Selenium	U	U	NC	20
Silver	U	U	NC	20
Thallium	U	U	NC	20
Tin	U	U	NC	20
Vanadium	U	U	NC	20
Zinc	U	U	NC	20

From: Lyons, Larry A
Sent: Friday, September 26, 2008 12:40 PM
To: 'Andrea Colby'
Cc: Johnson, John M; Wentz, Erica L
Subject: RE: Project 0356 TCLP Metals
Andrea,

The 10 samples that were marked for TCLP analyses have been cancelled. Would you please ship those samples back to us next week. The samples are identified as follows:

356-0006
356-0007
356-0008
356-0009
356- 0010
356-0048
356-0049
356-0050
356-0051
356-0052

Thank you,

Larry A. Lyons
Lockheed Martin/REAC
4890 Woodbridge Ave.
Bldg 209 Annex
Edison, NJ 08037

Phone: 732-494-4075

From: Johnson, John M
Sent: Friday, September 26, 2008 8:21 AM
To: Andrea Colby
Cc: Lyons, Larry A
Subject: RE: Project 0356 TCLP Metals

Yes, your only doing the 18 metals that was on the original bid list.

From: Andrea Colby [mailto:acolby@katahdinlab.com]
Sent: Thursday, September 25, 2008 4:39 PM
To: Johnson, John M
Subject: RE: Project 0356 TCLP Metals

Hi John,
The COC is marked for TAL metals plus tin. Please confirm we are only doing the 18 metals in the bid request.
Thanks,
Andrea

From: Johnson, John M [mailto:john.m.johnson@lmco.com]
Sent: Thursday, September 25, 2008 8:13 AM
To: acolby@katahdinlab.com
Cc: Lyons, Larry A; Wentz, Erica L
Subject: Project 0356 TCLP Metals

Andrea please do not analyze the samples marked for TCLP analysis that you should receive today on COC 356-09/24/08-0009. Please just hold for further instructions.

S85322

0356-DAR-110308

CHAIN OF CUSTODY RECORD

No: 356-09/15/08-0003

REAC, Edison, NJ

Laurence Harbor Site

Site #: 356

Contact Name: Larry Lyons

Contact Phone: (732)494-4075

Lab: Katahdrin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0023	RM-1	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz. glass jar	-20 C/Dry Ice	*
	356-0024	RM-2	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz. glass jar	-20 C/Dry Ice	
	356-0025	RM-3	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz. glass jar	-20 C/Dry Ice	
	356-0026	RM-4	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz. glass jar	-20 C/Dry Ice	
	356-0027	RM-5	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz. glass jar	-20 C/Dry Ice	
	356-0028	RM-6	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz. glass jar	-20 C/Dry Ice	

ew

019

Special Instructions: * Lab chooses sample for MS/MSD analysis; All samples to be homogenized

SAMPLES TRANSFERRED FROM CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analyses	L. A Lyons	9/18/08									

0000008

0356-DAR-110308

REAC, Edison, NJ

Laurence Harbor Site

CHAIN OF CUSTODY RECORD

Site #: 356

Contact Name: Larry Lyons

Contact Phone: (732) 494-4075

No: 356-09/15/08-0004

Lab: Katahdrin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0029	Mya-1	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	*
	356-0030	Mya-2	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0031	Mya-3	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0032	Mya-4	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0033	Mya-5	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	

EW

020

Special Instructions: * Lab chooses sample for MS/MSD analysis; All samples to be homogenized

SAMPLES TRANSFERRED FROM CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analyses	L. A. Lyons	9/18/08									

000009

0356-DAR-110308

REAC, Edison, NJ

Laurence Harbor Site

CHAIN OF CUSTODY RECORD

Site #: 356

Contact Name: Larry Lyons

Contact Phone: (732) 494-4075

No: 356-09/15/08-0005

Lab: Katahdrin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0034	Mer-1	TAL Metals plus Sn, % Solids	Tissue	9/11/2008	1	4 oz. glass jar	-20 C/Dry Ice	*
	356-0035	Mer-2	TAL Metals plus Sn, % Solids	Tissue	9/11/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0036	Mer-3	TAL Metals plus Sn, % Solids	Tissue	9/11/2008	1	8 oz. glass jar	-20 C/Dry Ice	

LW

021

Special Instructions: *Lab chooses sample for MS/MSD analysis ; All samples to be homogenized

SAMPLES TRANSFERRED FROM CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analyses	L.A. Lyons	9/18/08									

0000010

R2-0006891

0356-DAR-110308

REAC, Edison, NJ

Laurence Harbor Site

CHAIN OF CUSTODY RECORD
Site #: 356
Contact Name: Larry Lyons
Contact Phone: (732) 494-4075

No: 356-09/15/08-0006

Lab: Katahdrin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0037	FF-1	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz glass jar	-20 C/Dry Ice	*
	356-0038	FF-2	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz glass jar	-20 C/Dry Ice	
	356-0039	FF-3	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz glass jar	-20 C/Dry Ice	
	356-0040	FF-4	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz glass jar	-20 C/Dry Ice	
	356-0041	FF-5	TAL Metals plus Sn, % Solids	Tissue	9/10/2008	1	8 oz glass jar	-20 C/Dry Ice	

ew

022

Special Instructions: * Lab chooses sample for MS/MSD analysis; All samples to be homogenized

SAMPLES TRANSFERRED FROM
CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analyses	L. A. Lyons	9/18/08									

000011

R2-0006892

0356-DAR-110308

REAC, Edison, NJ

Laurence Harbor Site

CHAIN OF CUSTODY RECORD

Site #: 356

Contact Name: Larry Lyons

Contact Phone: (732) 494-4075

No: 356-09/15/08-0007

Lab: Katahdrin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0042	Ulva-1	TAL Metals plus Sn, % Solids	Plant Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	*
	356-0043	Ulva-2	TAL Metals plus Sn, % Solids	Plant Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0044	Ulva-3	TAL Metals plus Sn, % Solids	Plant Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0045	Ulva-4	TAL Metals plus Sn, % Solids	Plant Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	
	356-0046	Ulva-5	TAL Metals plus Sn, % Solids	Plant Tissue	9/10/2008	1	4 oz. glass jar	-20 C/Dry Ice	

ew

023

Special Instructions: * Lab chooses sample for MS/MSD analysis ; All samples to be homogenized

SAMPLES TRANSFERRED FROM

CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analyses	L. A. Lyons	9/18/08									

000012

R2-0006893

SB5405

0356-DAR-110308

CHAIN OF CUSTODY RECORD

No: 356-09/24/08-0009

REAC, Edison, NJ

Laurence Harbor Site

Site #: 356
Contact Name: Larry Lyons
Contact Phone: (732) 494-4075

Lab: Katahdin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0006	RBS-S01A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0007	RBS-S02A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0008	RBS-S03A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0009	RBS-S04A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0010	RBS-S05A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0011	SS-RM1	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0012	SS-RM2	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0013	SS-RM3	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0014	SS-RM4	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0015	SS-RM5	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0016	SS-RM6	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0017	SS-MM1	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0018	SS-MM2	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0019	SS-MM3	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0020	SS-MM4	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0021	SS-MM5	TAL Metals plus Sn, % Solids	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0022	Sediment Blank	TAL Metals plus Sn, % Solids, TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0047	PW-A1 (Total/Unfiltered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	250 mL bottle	4 C	

024

Special Instructions: Lab chooses sample for MS/MSD analysis on both the sediment and the pore water samples.
Pore water samples are also preserved with pH < 2

SAMPLES TRANSFERRED FROM
CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analysis	L. A Lyons	9/24/08	[signature]	9-25-08	1000						

000010

SB5405

0356-DAR-110308

REAC, Edison, NJ

Laurence Harbor Site

CHAIN OF CUSTODY RECORD

Site #: 356

Contact Name: Larry Lyons

Contact Phone: (732) 494-4075

No: 356-09/24/08-0009

Lab: Katahdin Analytical

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
	356-0048	RBS-507A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0049	RBS-S59A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0050	RBS-S60A	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0051	RBS-S97	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0052	RBS-S98	TCLP	Sediment	9/11/2008	1	4 oz. glass jar	4 C	
	356-0053	PW-A2 (Filtered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	175 mL bottle	4 C	
	356-0054	PW-B1 (Total/Unfiltered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	250 mL bottle	4 C	
	356-0055	PW-B2 (Filtered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	175 mL bottle	4 C	
	356-0056	PW-C1 (Total/Unfiltered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	250 mL bottle	4 C	
	356-0057	PW-C2 (Filtered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	175 mL bottle	4 C	
	356-0058	PW-D1 (Total/Unfiltered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	250 mL bottle	4 C	
	356-0059	PW-D2 (Filtered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	175 mL bottle	4 C	
	356-0060	PW-E1 (Total/Unfiltered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	250 mL bottle	4 C	
	356-0061	PW-E2 (Filtered)	TAL Metals plus Sn	Pore Water	9/22/2008	1	175 mL bottle	4 C	

025

Special Instructions: Lab chooses sample for MS/MSD analysis on both the sediment and the pore water samples.
Pore water samples also preserved with pH<2

SAMPLES TRANSFERRED FROM
CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
Analysis	L A Lyons	9/24/08	[illegible]	9-25-08	1000						

000011

APPENDIX C

PHOTOGRAPHS OF SLAG SAMPLES


Figure C-1: Sample SW-1


Figure C-2: Slag Boulder (SW-2)


Figure C-3: Sample SW-2


Figure C-4: Sample SW-3


Figure C-5: Sample SW-3


Figure C-6: Sample SW-4


Figure C-7: Sample SW-5 -Exterior


Figure C-8: Sample SW-5 - Interior


Figure C-9: Slag BoulderJetty-1


Figure C-10: Slag Boulder Jetty-1


Figure C-11: Jetty-2A- exterior


Figure C-12: Jetty-2B- interior


Figure C-13: Jetty-3A- exterior


Figure C-14: Jetty-3B- interior


Figure C-15: Jetty-4 interior


Figure C-16: Jetty-5 Melted Conglomerate


Figure C-17: Jetty-5


Figure C-18: Jetty-6


Figure C-19: Jetty-7A - Exterior


Figure C-20: Jetty-7B- Interior


Figure C-21: West Jetty(WJ)-1


Figure C-22: West Jetty(WJ)-2

REPORT

2 of 2
RARITAN BAY SLAG SITE

OLD BRIDGE TOWNSHIP, NEW JERSEY

BIOLOGICAL ASSESSMENT

ECOLOGICAL RISK ASSESSMENT

April 2010

Prepared
by
Mark Sprenger, Ph.D.
EPA/ERT

and

Larry Lyons

U.S. EPA Work Assignment No.: 0-356
Lockheed Martin Work Order No.: EAC00356
U.S. EPA Contract No.: EP-C-04-032

0356-DFR-013109

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APPENDIXCES

LIST OF TABLES

R2-0006905

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AE	assessment endpoint
Ag	Silver
As	Arsenic
AUF	area use factor
BERA	baseline ecological risk assessment
BM	benchmark
BW	body weight
cm	centimeter
COPC	contaminants of potential concern
Cr	Chromium
Cu	Copper
dw	dry weight
g	gram
EC	environmental concentration
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
GPS	Global Positioning System
HQ	Hazard Quotient
kg/day	kilograms per day
LD_{50}	lethal dose to half of the exposed organisms
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
mg/kgBW/day	milligrams per kilogram body weight per day
mm	millimeter
Mn	Manganese
NA	not applicable
ND	not determined
Ni	Nickel
NJ	New Jersey
NOAEL	no observable adverse effect level
oz	ounce
Pb	Lead
ppm	parts per million
QA/QC	quality assurance/quality control
REAC	Response, Engineering and Analytical Contract
Sb	Antimony
SLERA	Screening-Level Ecological Risk Assessment
SMDP	Scientific Management Decision Point
Sn	Tin
TAL	Target Analyte List
TCLP	Toxicity Characteristic Leaching Procedure
TRV	toxicity reference value
U	not detected
UCL	upper confidence level
µg/L	microgram per liter
Zn	Zinc
%	percent

Results from this effort are presented in two separate documents. The first document is the Chemical Assessment Report (EPA/ERT/REAC 2009) presenting data collected, and an interpretation of data relative to nature, fate and transport of the metal contaminants related to slag boulders and debris associated with the seawall and Cheesequake Creek Jetty. This document presents an initial ERA, providing assessment of the impact of metals being released and transported from the slag boulders and debris to the biological communities inhabiting and or utilizing the intertidal zone adjacent to the seawall.

The intertidal zone adjacent to the seawall provides the appearance of a typical coastal marsh grass (*Spartina*) ecosystem. Shore birds, including Brandt and Canada geese grazing on either the *Ulva* or *Spartina*, plovers searching for invertebrates, and killideer nesting, are common observations within this intertidal zone. However, an impairment of this intertidal ecosystem was indicated based on field observations of the invertebrate community during the site investigation. This intertidal ecosystem immediately adjacent to the seawall supported a limited invertebrate fauna with only two sessile invertebrates prevalent, that is, adult ribbed mussels and juvenile *Mya* or steamer clams. All of the juvenile *Mya* clams were less than one-year old with no adult clams found. In addition, only a limited Polychaete community was found, such that the proposed collection of these organisms could not be completed.

The intertidal plant community of this ecosystem was dominated by two plants (*Spartina* and the macro algae *Ulva*) growing along the entire reach adjacent to the seawall. *Ulva* was selected to biomonitor the accumulation of metals into plant tissue. Arsenic, Cr, Pb, Mn and Ni accumulated in *Ulva* at higher levels than in mollusks. This accumulation of metals in the *Ulva* would lead to the expectation that the roots, stems and leaves of the *Spartina* would also contain contaminants. The bioaccumulation of Site related metals in the biota at the levels observed confirms the release of these contaminants from Site waste material, as suggested by the laboratory leaching data.

The ecological risk assessment (ERA) conducted here, follows Superfund guidance, and utilized a systematic approach for selecting hazard and exposure parameters incorporating the selection of both conservative and more representative (less conservative) inputs for risk calculations. In addition the ERA conducted here is a "focused" ERA evaluating only targeted assessment endpoints.

Risk to the intertidal invertebrate community was characterized based on exposures of metals in sediments, pore water and surface water. Chronic toxicity benchmarks were exceeded from measured exposure concentrations of As and Pb in the sediment, from measured As, Mn, and Pb exposures in pore water, and from measured As, Cu and Pb exposures in surface water. In addition, the intertidal invertebrate community is at risk based on acute toxicity benchmarks from measured exposure concentrations of As in pore water and measured Cu and Pb exposures in surface water. Given the fact that calculated risk is based on both acute and chronic benchmarks relative to mean, 95% Upper Confidence Limit (UCL) and/or maximum exposure concentrations, calculated risk to this intertidal invertebrate community is not overestimated. In addition, impairment of the intertidal zone was indicated based on low diversity of invertebrate fauna observed and absence of certain fauna and life-stages; thereby, further supporting these risk conclusions.

Fecundity and Early-life Stage Development of the Horseshoe Crab are at risk based on the same risk calculations for As, Pb, and Cu exposures in sediment, pore water and surface water which characterized risk to the intertidal invertebrate community. Adult horseshoe crabs are known to come ashore in the bays of Monmouth and Middlesex Counties including Raritan Bay to construct shallow nests within the intertidal zone, lay and fertilize their eggs. Development of the embryos and the larval stages of the horseshoe crab are at risk from metal contamination in sediments, pore water and surface water within this intertidal zone.

Risk to the invertivorous shore birds was characterized based on dietary exposure models using the semipalmated plover as the receptor species. Model calculated risk indicated that As and Pb in the sediments was driving risk based on the most conservative model using the 95% UCL sediment exposures and the maximum food (mollusks) intake exposures. When the more representative dietary exposure models were applied using the mean sediment and mean food intake exposures, risk was being driven by Pb. In addition, the invertivorous shore birds may be at risk based on acute exposure to Pb. Acute TRVs for Pb derived for the semipalmated plover are within the same range as the 95%UCL and maximum concentrations of Pb measured in the sediments within the intertidal zone.

Risk to the herbivorous shore birds was characterized based on dietary exposure models using the Canada goose as the receptor species. Model calculated risk indicated As, Cr and Pb in sediments was driving risk based on the most conservative model using the 95% UCL sediment exposures and the maximum food (*Ulva*) intake exposures. It could not be concluded there was no calculated risk from exposure to Pb when representative dietary exposure models were applied.

In addition, the presence of elemental lead particles (especially at the jetty area) and particles of waste material may pose a risk to all avian receptors. This risk would be the result of ingestion of particle for use within the bird's crop, the same mechanism of exposure which occurs from the ingestion of lead pellets by waterfowl. No attempt was made to quantify this risk for the Site.

1.0 INTRODUCTION

Raritan Bay Slag site (the Site), located in Old Bridge Township, New Jersey (NJ), is approximately 1.3 miles in length and consists of the waterfront area between Margaret's Creek and the area just beyond the western jetty at the Cheesequake Creek Inlet. The Site consists of a sea wall which extends for approximately 3,000 feet along Old Bridge Waterfront Park adjacent to Bayview Drive in Laurence Harbor, public beach areas, three jetties, the Cheesequake Creek outlet jetty which extends for about 1,000 feet from the mouth of the Cheesequake Creek into Raritan Bay, and the waterfront area west of the jetty (Figure 1).

In September 1972, the New Jersey Department of Environmental Protection (NJDEP) was advised by a local environmental commission member that lead-bearing waste material was being deposited along the Laurence Harbor beachfront. The material was reported to be non-recoverable, low-yield metallic waste from a blast furnace and blast furnace rubble. The slag was deposited at the beachfront in the late 1960s and early 1970s (mostly in the form of blast furnace pot bottoms) in an area that had sustained significant beach erosion and damage due to a series of storms in the 1960s. Also placed along the beachfront was a variety of bricks and fire bricks. A portion of the seawall also contains large riprap believed to have been placed over the slag when the grassed and paved portion of the park was developed.

The western jetty at Cheesequake Creek has been in existence since the United States (U.S.) Army Corps of Engineers constructed it in the late nineteenth century. The slag was reportedly placed on the jetty during the same general time period in which the seawall was created. The entire jetty is covered with slag that is similar in appearance to that which is present on the seawall. The waste material and slag were used to construct the jetty and also used as a fill and stabilizing material for the seawall. Metal contaminants associated with the slag and associated waste material include antimony (Sb), arsenic (As), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), zinc (Zn), and tin (Sn).

This effort performed both chemical and biological assessments within the study area. The results of these investigations are presented as separate reports, a chemical assessment report and the current document. The Chemical Assessment report (EPA/ERT/REAC 2009) provided the following:

- characterized the high metal concentrations within the slag boulders, particularly As, Cu, Pb, Sb, Sn and Zn;
- identified the dominant metal species, particularly for Pb, Cu, As and Sn in the slag boulders;
- assessed the leaching ability and/or mobility of the metals, particularly for Pb and Cu, associated with the slag when exposed to acidic exposures following Toxicity Characteristic Leaching Procedure (TCLP) methods;
- assessed the potential leaching ability and/or mobility of the metals, particularly for Pb, from the slag boulders when exposed to neutral salt solution;
- characterized the concentrations of metals to the abiotic media (sediments and pore water) within the intertidal zone adjacent to the seawall; and
- characterized the bioaccumulation potential of the metals by the predominant biota utilizing the intertidal zone along the seawall.

The objective of this report is to provide an ERA evaluating the risk/impact of the metals being released from the waste rocks/slag associated with the seawall on the biological communities inhabiting and/or utilizing the intertidal zone adjacent to the seawall. It must be noted that this report does not constitute the ecological risk assessment portion of the Remedial Investigation (RI) of the baseline risk assessment. This ERA is an initial and focused ecological risk assessment utilizing the data which exists and was generated as part of the investigations on the chemical nature and extent of contamination work conducted through the Removal Program. The ERA focuses on selected contaminants from the TAL list (including the metals which have been identified as Site related contaminants) and on selected assessment endpoints.

1.1 Ecological Risk Assessment Guidance

This ERA was conducted in accordance with the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (EPA 1997) and *Guidelines for Ecological Risk Assessment* (EPA 1998).

1.2 Overview of Ecological Risk Assessment Process

ERAs are used to evaluate the likelihood of adverse ecological effects occurring as a result of exposure to environmental stressors (defined as any physical, chemical, or biological entities that can induce adverse responses at a site). Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), risks from CERCLA-regulated chemicals are evaluated. This process involves identifying potentially affected ecological receptors and identifying pathways of exposure. The goal of an ERA is to enable Site managers to make informed decisions about the management of ecological resources.

1.3 Eight-Step Process for Conducting an Ecological Risk Assessment

An eight-step process for conducting an ERA is identified within Superfund Guidance (EPA 1997).

Steps 1 and 2 of the Guidance describe the initial screening-level ERA (SLERA).

In Step 1, the screening-level problem formulation and ecological effects evaluation, descriptions are developed: of the environmental setting; contaminants known or suspected to exist at the site and the maximum concentrations present within each medium; contaminant fate and transport mechanisms that might exist; mechanisms of ecotoxicity associated with the contaminants and categories of receptors that may be affected; potentially complete exposure pathways; and screening ecotoxicity values equivalent to chronic No Observable Adverse Effects Levels (NOAELs) based on conservative assumptions.

In Step 2, the screening-level preliminary exposure estimate and risk calculation are estimated by comparing maximum measured exposure concentrations with the ecotoxicity screening values developed in Step 1. Based on the outcome, the risk manager decides either the SLERA is adequate to determine ecological threats are negligible, or the process should continue to the more detailed ERA outlined in Steps 3 through 8 of the Guidance.

During an ERA, potential threats to ecological receptors from exposure to site-related contaminants are evaluated further. This process can be divided into three phases: problem formulation, analysis, and risk characterization (EPA 1998). These three phases encompass Steps 3 through 7 of the Superfund eight-step ERA process.

Steps 3 and 4 of the eight-step process described in the Superfund Guidance (EPA 1997) are the problem formulation stage of the ERA. During Step 3, the screening-level problem formulation is refined and expanded upon, and additional site-specific information is used to determine the scope and goals of the risk assessment. This step involves the refinement of the list of contaminants of concern, refinement of contaminant fate and transport mechanisms, additional characterization of ecological effects of contaminants, selection of assessment endpoints, and refinement of information about exposure pathways. Assessment endpoints may include species, ecological resources, or habitat types which are considered of value, and will be used to guide the development of the study design at the site

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Step 3 initiates the development of a site conceptual model which integrates the components identified during problem formulation. This conceptual model describes the ecosystem or ecosystem components potentially at risk, presents a series of working hypotheses about how exposure to contaminants might affect the ecological components of an ecosystem, and details the relationships between measures of effects (changes in the attributes of assessment endpoints as a response to the stressors to which they are exposed) and exposure scenarios.

Step 4 of the eight-step Superfund process, Study Design and DQO Process, defines the analysis plan and is the final stage of the ERA problem formulation. The analysis plan specifies the data required to evaluate risks to the assessment endpoints and methods that will be used in analyzing the data. Risk hypotheses are evaluated to determine how they will be assessed. The plan includes a delineation of the assessment design, and identifies data needs, measures, and methods for conducting the analysis phase and the risk characterization phase with the emphasis on evaluating risk from chemical stressors regulated under CERCLA.

During the problem formulation stage of the ERA it is possible (and not technically incorrect) to start at different components (e.g., toxicity evaluation, identification of assessment endpoints, development of a conceptual model, investigation of exposure pathways) and still arrive at the same risk hypotheses. This document however will begin with the identification of the ecological components of the ecosystem at risk (ecological setting, exposure pathways, contaminant fate and transport) followed by toxicity evaluation (ecological effects of contaminants) and identification of assessment endpoints, leading to the development of the site conceptual model and risk hypotheses.

The analysis stage of the ERA includes Steps 5 (verification of field sampling design) and 6 (site investigation and data analysis) of the Superfund eight-step process. This phase involves the creation of life-history and toxicity profiles for estimating and characterizing the exposure of ecological assessment endpoints to stressors, and establishing the relationships between stressor levels and ecological effects.

The final stage of the ERA, and Step 7 of the Superfund process, is risk characterization. This is the process of estimating risk through the integration of exposure and stressor-response profiles, and providing the information necessary for interpreting risk estimates.

Step 8, risk management, in which the risk manager integrates the risk assessment results with other considerations (e.g., background levels of contamination, available cleanup technologies, and costs of alternative actions and remedy selections) to make and justify risk management decisions will not be addressed in this document.

2.0 FOCUSSED SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT (SLERA)

Screening level problem formulation and ecological effects evaluation

2.1 Site Setting

The Site, situated in residential areas on Raritan Bay in New Jersey, is bordered to the south, east, and west by residential properties and State Highway 35 and to the north by Raritan Bay. The Site, extending for approximately 1.3 miles, includes the Old Bridge Waterfront Park, public beaches, three jetties, Cheesequake Creek Inlet jetty and the waterfront area west of the jetty (Figures 1, 2 and 3). Old Bridge Waterfront Park, consisting of walking paths, gazebo and a public parking area which is protected by a seawall, constructed with layers of slag boulders and fill. Slag boulders and fragments of slag are scattered along the entire length of the beach area between the seawall and cordgrass (*Spartina alterniflora*) beds (Picture 1). Picture 2 depicts the slag boulders at the top of the seawall during high tide. Picture 3 and 4 depict an assortment of slag boulders and waste material used for constructing the jetty.

2.2 Intertidal Zone Along Seawall

Picture 1 depicts the area along the seawall within the intertidal zone at low tide with the *Spartina* beds situated adjacent to the seawall. The intertidal zone adjacent to the seawall (Figures 1 and 2) consists of an open stretch of beach with large boulders of slag and slag debris extending for 20 to 30 feet before reaching the *Spartina* beds. The *Spartina* beds extend for 10 to 15 feet within the mid to high tide range of the intertidal zone along the entire length of the seawall. The intertidal zone immediately beyond the *Spartina* beds primarily consists of open sand beach, cobble stones to medium sized rocks and randomly scattered slag. The green macro algae (*Ulva* sp) were attached to the bottom substrate on the cobble stones and rocks within this area extending from the mid tidal level to beyond the low tidal level. It was noted the *Ulva* did not colonize or attach to the slag that was scattered in this area. The *Ulva* was prominent but was not growing profusely within this intertidal zone (Picture 5).

Invertebrates prevalent in the intertidal zone either within or in proximity of the *Spartina* beds were limited to two species of mollusks – ribbed mussel (*Geukensia demissa*) and long neck or steamer clam (*Mya arenaria*). A dense colony of ribbed mussels was situated within the *Spartina* beds buried just below the surface of the sediments with a portion of the bivalve shell slightly extending above the surface of the sediments, allowing for their siphon to be extended into the water column for filtering. Most of the *Mya* clams were completely buried in the sediments from just below the surface to depths of six to eight inches. The hard shell clam (*Mercenaria mercenaria*) was found inhabiting the subtidal zone just beyond the intertidal zone. The hard shell clams were buried in the sediment at just below the surface.

Adult exoskeletons of the horseshoe crab (*Limulus polyphemus*) were observed at the site. Horseshoe crabs are known to come ashore to the sandy beaches of local bays in Monmouth and Middlesex counties in May/June to begin the spawning season.

2.3 Screening Level Site Conceptual Model and Exposure Pathways

The screening level site conceptual model is based on the site setting and identified exposure pathways linking contaminants to the assessment endpoints. Figure 4 presents the conceptual model providing an overview depicting the transport and fate of the metal contaminants originating from known source material to the assessment endpoints. Within the screening level conceptual model exposure pathways are assumed to be complete and substantive.

2.4 Screening Level Assessment Endpoints and Measures of Effect

Four assessment endpoints were identified for use in this focused ERA, these assessment endpoints are:

Assessment Endpoint #1: Survival, Growth and Reproduction of Intertidal Invertebrate Community;
Assessment Endpoint #2: Fecundity and Early-Life Stage Development of the Horseshoe Crab;
Assessment Endpoint #3: Survival, Growth, and Reproduction of Invertivorous Shore Birds; and
Assessment Endpoint #4: Survival, Growth, and Reproduction of Herbivorous Waterfowl.

NOTE: Since this is a focused ERA, the list of assessment endpoints is limited. In addition a more complete discussion of these assessment endpoints is presented in Section 3 of this report.

2.5 Characterization of Effects
Ecological Effects – at the screening level effects are assumed to be substantive for contaminants present.

The methods on the characterization of effects and the decision criteria for the elimination or retention of COPCs are provided.

2.6 Eco-toxicological Benchmark Values
Eco-toxicological screening benchmarks are concentrations of chemicals that are reasonably considered to be the highest acceptable concentration at/or below which there should be no adverse environmental effects. For this SLERA the sediment BMs were derived from the Marine/Estuarine Sediment Screening Guidelines for low effects ranges (ERL) provided by the NJDEP (1999). Saltwater benchmark values (BMs) were used for defining the surface water and pore water BM which were derived from National Recommended Water Quality Criteria for Seawater (EPA 2002).

2.7 Decision Criteria for Elimination or Retention of COPCs
The hazard quotient (HQ) method was used in this SLERA to evaluate risk from the analytes. This method compares the exposure (estimate) concentration (EC) to BM and is expressed as a ratio:

$$HQ = EC / BM$$

The EC is the maximum concentration of the COPC and the BM represents the “no effect” concentration for that metal for surface water, pore water or sediment.

A HQ equal to or greater than 1.0 indicates there is the potential for risk from direct or abiotic exposure to a COPC at concentrations measured on-site and further evaluation is warranted. A HQ of less than 1.0 suggests there is a high degree of confidence that minimal or no risk exists for the given COPC. Metals for which benchmark values are not available were retained as COPCs.

2.8 Screening Level Preliminarily Exposure Estimation and Risk Calculation
The selected measure of effects for all of these assessment endpoints is the use of a hazard quotient (HQ), which uses the maximum concentration reported in appropriate abiotic media (soil/sediment, surface water or pore water) to the appropriate screening level benchmark (e.g. the ambient water quality criteria or the New Jersey State Sediment Effects Range Low -ERLs) .

2.9 Characterization of Exposure

Surface water, pore water and sediment data collected within the intertidal zone were used in this SLERA. The data, presented in the Chemical Assessment report (EPA/ERT/REAC 2009), was generated from the site sampling events in September 2008 originating from the sampling performed under this WA and sampling performed for EPA Region II by Weston Solutions, Inc (2009). The maximum concentrations of each metal for each environmental media were used to characterize exposure.

2.10 Risk Characterization

The HQs are presented by media rather than by assessment endpoints in an effort to reduce redundancy within this report.

Risk to the assessment endpoints assessed as described above. Tables 1, 2, and 3 identify the COPCs (metals) retained based on either the surface water, pore water and sediment benchmarks being less than the maximum exposure concentrations or because no benchmark was available. Tables 1, 2, and 3 also identify the metals which will not be retained based on maximum exposure concentrations not exceeding the benchmarks.

2.11 Scientific Management Decision Point

The conclusions derived from this SLERA are:

• Tables 1 and 2 identified between four to seven metals (Sb, As, Cu, Pb, Mn, Ag and Sn) in either the surface water and/or pore water to be retained for the ERA based the HQ being greater than 1 for the media or no benchmark was available. Table 3 identified seven metals (Sb, As, Cu, Pb, Mn, Ag and Zn) in sediment being retained based the HQ being greater than 1 for the media concentrations or no benchmark was available.

• Three metals (Cr, Ni and Zn) were identified in the pore water and two metals (Cr and Ni) in the sediments (Tables 2 and 3) were not retained as COPCs since the HQ was less than 1.0.

• Screening level HQ values for COPCs identified in the surface water, pore water and sediments indicate a potential for ecological risk exists. The risk assessment process will continue to Step 3 based on the retention of the COPCs.

3.0 PROBLEM FORMULATION

The problem formulation, incorporating Steps 3 and 4 of the eight-step Superfund process, is a systematic planning process identifying the factors to be addressed in the ERA as follows:

- site setting;
- review of potential ecological effects of the contaminants of concern at this site;
- review on fate and transport of the environmental contaminants, on potential exposure pathways, and on the biota potentially at risk;
- development of a conceptual model;
- selection of assessment and measure of effects with testable hypotheses (or risk questions) which the ERA will address; and
- analysis plan (Step 4) describing the details of the site investigation, data analysis methods and data quality objectives.

3.1 Site Setting

The site setting is provided in section 2.1.

3.2 Contaminant Fate and Transport

The Chemical Assessment report (EPA/ERT/REAC 2009) characterized the concentrations of metals associated with the slag boulders/waste material at the Site.
A literature search was conducted to obtain information on the fate and transport of the metal contaminants; this information is presented in Appendix A.

3.3 Ecological Effects

A literature search was conducted to obtain information on the ecological effects for all of the COPCs. Literature was reviewed to provide a general overview of the toxicity and toxic mechanisms for a given COPC for various exposure routes. Toxicological profiles for the COPCs to birds are presented in Appendix B. Toxicity reference values (TRVs) used to evaluate risk to shore birds are presented in Table 4

Toxicological BMs for the intertidal biota were derived for sediments, surface water and pore water. The sediment BMs were derived from the Marine/Estuarine Sediment Screening Guidelines for low and medium effects ranges (ERL and ERM) provided by the NJDEP (1999). Surface water BMs were used for defining the surface water and pore water BMs that were derived from National Recommended Water Quality Criteria for Seawater (EPA 2002). These BMs will be used to assess risk to the intertidal fauna.

3.4 Site Conceptual Model and Exposure Pathways

The site conceptual model is based on contaminant and habitat characteristics and is used to identify critical exposure pathways linking contaminants to receptors. Figure 4 presents the conceptual model providing an overview depicting the transport and fate of the metal contaminants originating from slag boulders used to construct the sea wall and the Cheesequake Creek Inlet jetty to the intertidal zone. There are several physical and weathering processes including precipitation, ground water intrusion and wave or surf action that would be responsible for the gradual weathering and erosion of the slag boulders and debris along the sea wall. For the jetty, wave or surf action and precipitation would be the physical components responsible for the erosion and weathering of the slag. The gradual weathering of the slag boulders allows interior layers of the slag to be exposed, ultimately releasing metal species which have a higher affinity for leaching. The metal contaminants being released are transported to the sediments, pore water and surface water within the intertidal zone.

Cordgrass (*Spartina*) and macro algae (*Ulva*), the dominant intertidal flora, are in direct contact with the sediments, and/or pore water and/or surface water for bioaccumulating the metal contaminants. The intertidal flora could also be indirectly affected from metal contamination by changes in ecosystem functions and energy transfer which are important in growth and reproduction. Seasonal biodegradation (die back) of the flora would be expected to recycle the metal contaminants they have bio-accumulated back to the ecosystem.

The intertidal invertebrate fauna (mollusks, polycheate worms, etc.) would also be in direct contact with the sediment, pore water and surface water that may be detrimental to development, growth and reproduction. Additional exposures may result from ingesting contaminated food items. The invertebrate community may also be indirectly affected by a change in ecosystem functions, such as nutrient cycling and energy transfer. Likewise, the forage fish community utilizing the intertidal zone would be in direct contact with contaminated sediments and surface water as well as ingesting contaminated food items.

The intertidal zone provides the appropriate habitat for horseshoe crabs to utilize for nest building, fertilization of eggs, and development of the embryos, larvae and juveniles. Both the breeding and the early development stages of the horseshoe crab are in direct contact with the sediments, pore water, and surface water in the intertidal zone.

Shore birds would also utilize the intertidal zone for foraging and can be exposed to contaminants through ingestion of food items. Additionally, they may also be exposed to contaminants through ingestion of water, incidental ingestion of sediment and direct contact with sediment. Examples of shore birds which would utilize this intertidal zone include invertivores (e.g., semi-palmated plover), herbivores (e.g., Brant, Canadian goose), and piscivores (e.g., great blue heron, osprey).

3.5 Assessment Endpoints, Risk Hypothesis and Measure of Effect

Assessment endpoints (AEs) are explicit expressions of the actual environmental values (i.e., ecological resources) that are to be protected. Valuable ecological resources include those without which ecosystem function would be significantly impaired, or those providing critical resources (e.g., food, habitat). Appropriate selection of AEs is critical to the utility of an ERA, as it focuses assessment design and analysis. It is not practical or possible to directly evaluate risks to all the individual components of the ecosystem on site, so AEs are used to focus on particular components that could be adversely affected by contaminants associated with the site.

AEs for this ERA are focused on a variety of organisms inhabiting or utilizing the intertidal zone adjacent to the seawall. While selection of AEs is an essential element of the problem formulation process, it is difficult or impossible to measure the effects on all the members of a receptor group associated with exposure to COPCs at the site. For this reason, it is necessary to articulate specific risk questions (*i.e.*, testable hypotheses) which can be answered through the collection of focused data at the site (*i.e.*, Measure of Effects).

Measures of effects are measurable ecological characteristics related to the AE; they are specific measures that address the testable hypotheses (EPA 1997, 1998).

The AE's, associated risk questions or testable hypotheses and Measure of Effects considered for this ERA are described below.

3.5.1 Assessment Endpoint #1: Survival, Growth and Reproduction of Intertidal Invertebrate Community

The intertidal invertebrate community plays a key role in the intertidal ecosystem functions of nutrient cycling and organic matter processing. They also serve as an important food source for invertebrates (crabs), fish, birds, and mammals.

Benthic invertebrates may be directly exposed to contaminants present in sediment, surface water, and pore water. The localized and/or stationary nature of many invertebrate species suggests a high potential for exposure and enables specific exposure routes and concentrations to be identified with a high degree of certainty.

Testable Hypothesis: Are concentrations of contaminants present in the surface water, pore water and sediments sufficient to adversely affect the survival or growth of intertidal invertebrates?

Measure of Effect: Measured COPC concentrations in surface water pore water and sediment from the intertidal zone will be determined and compared to sediment or salt water benchmark values.

Testable Hypothesis: Does the intertidal zone at this site provide suitable habitat for supporting a functioning benthic invertebrate community

Measure of Effect: Assess the diversity and condition of the biota inhabiting the intertidal zone.

3.5.2 Assessment Endpoint #2. Fecundity and Early-Life Stage Development of the Horseshoe Crab

The horseshoe crab (*Limulus polyphemus*) is an invertebrate belonging to the Phylum Arthropoda that utilizes the sandy beaches of New Jersey bays for spawning and early-stage development. The spawning season begins in the spring with the adult crabs moving from the deeper waters in the bay or continental shelf to the beaches. The female crab will form a shallow nest depositing up to 20,000 eggs. Fertilization occurs by either the male that is attached to the female or by satellite males. After fertilization, the eggs begin to develop into trilobite larvae which can take three to four weeks to hatch. Upon hatching, the trilobite larvae (at about 3 mm in size) dig out of the sand. The baby crabs swim around for about a week absorbing the yolk sac as their digestive system develops. They then settle from the water column onto the sediments and continue to molt into juvenile crabs.

Horseshoe crabs are an important part of the food web. The eggs are an important food source for migratory shore birds (i.e., red knots, ruddy turnstones and sanderlings). A number of fish in Raritan Bay feed on horseshoe crab eggs and larvae, including striped bass, white perch, killifish, weakfish, flounder, and various crab species. A high potential of exposure from COPCs to the early-life stages exists in surface water, pore water and sediments.

Testable Hypothesis: Are concentrations of contaminants present in the surface water, pore water and sediments sufficient to adversely affect egg fertilization and development of the early-life stages of the horseshoe crab?

Measure of Effects: Measured COPC concentrations in surface water pore water and sediment from the intertidal zone will be determined and compared to sediment or salt water benchmark values.

3.5.3 Assessment Endpoint #3. Survival, Growth, and Reproduction of Invertivorous Shore Birds

Invertivorous shore birds are mid-trophic organisms that rely primarily on the invertebrates inhabiting the intertidal zones of bays and coastal areas. Foraging behavior of aquatic feeding or shore birds represents a pathway by which nutrients and energy are transferred from aquatic to terrestrial ecosystems. Nutrients enter aquatic ecosystems via surface water runoff, stream input, and water infiltration through the soil. Energy enters aquatic ecosystems via sunlight and biological inputs such as detritus and marsh vegetation. Nutrients and energy are used to fix carbon in the production of plant and animal biomass, and are transferred from aquatic to terrestrial ecosystems through the food chain. Since nutrients and energy are limiting factors in the production of an ecosystem, the transfer of energy from an aquatic to a terrestrial system and back is essential. Birds provide one mechanism by which nutrients and energy are transferred from aquatic to terrestrial ecosystems and are therefore important in the maintenance of balanced nutrient and energy cycles.

Representative species of invertivorous shore birds include semipalmated plover, redknot, sanderlings, and egrets.

Testable Hypothesis: Does the daily dose of contaminants received by shore birds from consumption of the tissues of forage invertebrates and from other media at the Site exceed the TRVs for survival, growth or reproduction of birds?

Measure of Effects: Concentrations of COPCs in the tissues of prey species (*i.e.*, whole body tissue residues of mollusks) and sediment will be measured. The risk from dietary exposure to COPCs on-site will be determined using dietary exposure models. Exposure doses calculated using dietary models for shore birds (semipalmated plover), incorporating COPC concentrations in the mollusks and sediment, will be compared with TRVs derived from the literature.

3.5.4 Assessment Endpoint #4. Survival, Growth, and Reproduction of Herbivorous Shore Birds

Herbivorous birds rely primarily on vegetation as forage. The role of herbivores is essential within an ecosystem as they transfer the energy available in plant tissue (primary producers) to animal tissue, and make it available to upper trophic level organisms. Herbivorous birds also serve as prey for upper trophic level predators. Herbivorous birds are susceptible to exposure to contaminants, particularly inorganic contaminants, which can accumulate in and on plant tissues upon which they feed and they have the potential to accumulate these contaminants within their tissues.

Most shore birds are migratory. The variable mobility of potential avian receptors (with a relatively large home range, variable diet, and often seasonal residency) suggests the potential for exposure, identification of specific exposure routes and concentrations are associated with some uncertainty. Many species will exhibit focused foraging and directed feeding in the presence of seasonally available prey (e.g., based on growing and fruiting seasons) resulting in an increased exposure to contaminated food. Nonetheless, the herbivorous avian community is of concern due to its role in energy transfer and regulating populations, and potential for exposure and adverse effects in a mid-to higher trophic level organisms. Representative species of the herbivorous shore birds include Brandt and Canada goose

Testable Hypothesis: Does the daily dose of contaminants received by shore birds from consumption of plant tissue and other media at the Site exceed the TRVs for survival, growth or reproduction of herbivorous birds?

Measure of Effects: Concentrations of COPCs in the site-specific plant (macro algae) tissue (*i.e.*, tissue residues of *Ulva*) and sediment will be measured. The risk from dietary exposure to COPCs on-site will be determined using dietary exposure models. Exposure doses calculated using dietary models for shore birds (Canadian goose), incorporating COPC concentrations in the macro algae and sediment, will be compared with TRVs derived from the literature.

3.6 Analysis Plan

The objective of the sampling design was to document the release of contaminants from source areas and assess the fate and transport of the metals leaching from the slag and associated waste material. This objective was met utilizing both chemical analyses of abiotic media and evaluation of the uptake by the biota inhabiting or utilizing the intertidal and subtidal zones along the seawall. A biomonitoring approach was incorporated into the sampling design along with the analyses of sediment and pore water to evaluate the release and uptake of metals. The criteria for the selection of the criteria and or concepts for the selection of target biomonitoring species were taken from Boening 1999, Butler, P.A. 1971; Phillips, 1977; and Phillips, 1978, and are as follows:

- the organisms integrate exposure over time;
- the organisms feeding strategy and/or other behavior characteristics establish exposure pathways consistent with environmental chemistry of the contaminant of interest;
- the organism can concentrate contaminants and therefore, allow the evaluation of contaminants present in the environment at or below the analytical detection limit;
- the organism accumulates the pollutant without being adversely affected, if possible;
- the organism is an important foraging food source for higher level biota;
- the organism is sedentary (sessil) in order to be representative of the area of collection;
- the organism is abundant in the study area;
- the organism is sufficiently long lived to allow the sampling of more than one year class, if possible;
- the organism is of reasonable size to provide adequate tissue for analyses and accurate weight measurement;
- the organism is easy to collect/sample and hardy enough to survive in the laboratory, allowing depuration (clearing) before chemical analyses.

3.6.1 Organisms Chosen for Biomonitoring

The organisms chosen for the biomonitoring samplings were selected in an attempt to meet as many of the above criteria as possible given the species which are actually present at the Raritan Bay Slag Site. One of the primary considerations was the ability to bioaccumulate metals being released from the slag. In addition, there was consideration as to whether animals and plants at the site could potentially be consumed by human or ecological receptors (which increases the utility of the data generated). Based on the field reconnaissance of the sampling area and the organism selection criteria above, several target species were identified for sampling including mollusks (ribbed mussels, long necked clams and hard shell calm), polychaetes, macro algae (*Ulva*) and foraging fish (killifish).

3.6.2 Mollusks

Mollusks or bivalves are known to be effective biomonitors of metal contaminants meeting many of the criteria for an ideal biomonitoring organism. However, no one particular species is universally suitable. When possible and practical it is advisable to initiate biomonitoring assessments using several species to represent different exposure pathways (Boening 1999). The three prominent bivalves (ribbed mussel, long neck clam and hard shell clam) at this Site represent different feeding and/or habitat characteristics.

3.6.3 Macro Algae (Ulva)

Ulva species have demonstrated their capability as biomonitors of metal contamination including Cu, Pb, Ni and Zn (Baesada *et. at.* 2009; Talbot and Chegwidden 1982; Vilares *et.al.* 2005, 2001, 2002; Ho 1990). Both the laminar structure of these macro algae, providing a high surface area to volume ratio, and its capacity to grow in contaminated areas increased its potential as a useful biomonitor.

3.6.4 Killifish (*Fundulus*)

Killifish (*Fundulus* sp.) were the predominant foraging fish utilizing the intertidal zone at the Site. Additionally, killifish are known to have a limited seasonal home range (Lotrich, V.A. 1975). The killifish continuously move in and out of this intertidal zone with the tide and could potentially be exposed to the metals associated with the slag via surface water and foraging.

3.6.5 Polychaete

Polychaetes residing within the interstitial sediments of this intertidal zone would be in direct contact with sediment and pore water that could be contaminated with metals associated with the slag. However, the population density of the polycheate community within this intertidal zone was too small for effective sampling during the site investigation. Local residents were observed collecting worms to be used for bait along the beach area just east of the sea wall. Numerous worms were easily collected by the local residents with the use of a trowel. The largest worms ranged in size up to several inches in length. No evidence of these same types of worms was found along the seawall.

To integrate exposure from the environmental media at the same locations, sediment and pore water sampling was collocated with the biota sampling to the extent practical.

The site investigation activities occurred over four sampling days September 10, 11, 19 and 22, 2008. The sampling, analytical, and risk characterization methods are provided in the following sections.

3.6.6 Sampling and Analytical Methods

A total of 11 co-located sediment samples were collected at the ribbed mussel and Mya clam collection points. The sediment samples were collected after the ribbed mussels and *Mya* clams were collected to avoid disturbing the biota. Sediment samples were collected with a trowel and placed into 8-oz glass jars. Samples were shipped to the subcontract laboratory and were analyzed for target analyte list (TAL) metals and Sn.

3.6.7 Pore Water Sampling and Analytical Methods

Pore water samples were collected by inserting a glass pipette into the sediment at a depth of 1.5 to 2 inches below the surface. The end of the pipette inserted into the sediment was covered with nylon screen to prevent the entrainment of sediment. The pore water was siphoned through the pipette using a portable peristaltic pump. Individual decontaminated pipettes and tubing were used for collecting each sample. Five pore water samples were collected. Each of the samples was collected within proximity of the *Mya* clam collection points. The pore water was collected when the tide water had receded to avoid collection of surface water. One half of each sample volume was filtered by passing the water through a 0.45 micron (µm) filter and preserved to a pH of less than (<) 2.0 standard units with nitric acid and the other half of each sample was not filtered and preserved to pH < 2.0. Pore water samples were shipped to the subcontract laboratory and were analyzed for TAL metals and Sn as total metals and filtered metals.

3.6.8 Killifish (*Fundulus* sp.) Sampling and Analytical Methods

Five composite samples of killifish each consisting of eight individual fish were collected along the seawall during mid-tide using a seine net. Figure 2 presents the sampling area where the seining occurred. The killifish were placed into 2.5-gallon pails containing aerated seawater and transported back to the ERT/REAC Biological Laboratory for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into glass jars and frozen. Samples were shipped to the subcontract laboratory, homogenized and analyzed for target analyte list (TAL) metals, Sn and percent (%) solids.

3.6.9 Ribbed Mussel (*Geukensia demissa*) Sampling and Analytical Methods

Ribbed mussels were collected at six areas along the seawall at mid-tide. Figure 2 presents the six sampling locations designated as RM-1 to RM-6. The ribbed mussels were found to be prevalent amongst the *Spartina* (marsh grass) beds which are approximately 40 to 60 feet from the seawall. The ribbed mussels, most of which were seen projecting from the sediment, were collected by hand and ranged in size from 3.8 to 8.0 centimeters (cm). Eight to twelve ribbed mussels were collected at each sampling location to produce six composite samples. These samples were placed into large glass jars containing water, aerated and brought back to the ERT/REAC Biological Laboratory for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into a 16 ounce (oz) glass jar and frozen. The tissue was removed from each bivalve shell while frozen and the composite sample of the tissue was weighed. Tissue samples were shipped frozen to the subcontract laboratory homogenized and analyzed for TAL metals, Sn and % solids.

3.6.10 Long Neck Clam (*Mya arenaria*) Sampling and Analytical Methods

Mya clams were collected at five areas along the seawall at mid-tide within or near the *Spartina* beds. Figure 2 presents the five sampling locations (*Mya* 1 to *Mya* 5). The *Mya* clams were either observed partially buried in the sediment and collected by hand or were collected using a clam rake. The clams ranged in size from 1 to 4 cm with the number of individual clams in the composite samples ranging from 5 clams for *Mya*-3 to 106 clams for *Mya*-2. The clams were transported back to the ERT/REAC Biological Laboratory alive, placed into large glass flasks and aerated for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into a 16 oz. glass jar and frozen. The tissue from each clam was removed while frozen and the composite sample of tissue was weighed. Samples were shipped frozen to the subcontract laboratory, homogenized and analyzed for TAL metals, Sn and % solids.

3.6.11 Hard Shell Clam (*Mercenaria mercenaria*) Sampling and Analytical Methods

Mercenaria were collected using a "treading" and a clam rake at a water depth of 3.5 to 4 feet at mid-level tide just offshore of the sea wall. Figure 2 presents the approximate area from which the clams were collected. A total of 10 clams were collected of three different size ranges starting at 2.0 inches, 2.5 inches and 3.5 inches. The clams were subdivided into three composite samples based on the three size ranges. The clams were transported back to the ERT/REAC Biological Laboratory alive, placed into large glass flasks and aerated for a depuration period of 24 hours. Following the depuration period, each composite sample was weighed, placed into a glass jar and frozen. The tissue was removed from each clam while frozen and the composite sample of the tissue was weighed. Tissue samples were shipped frozen to the subcontracted laboratory, homogenized and analyzed for TAL metals, Sn and % solids.

3.6.12 Polychaete Sampling

Sampling for polychaete worms was performed by collecting sediment at the low to mid-tide level with a shovel, transferring the sediment onto a sieve and washing the sediment through the sieve to separate the polychaetes from the sediment. Collections were attempted at depths from just below the surface to a depth of approximately 10 inches. However, only a few small polychaetes (less than [<] 1 to 2 inches in size) were collected after sieving numerous sediment samples. This amounted to no more than 2.1 grams (g) wet weight providing an insufficient volume of biomass to meet the data quality objectives

3.6.13 Sea Lettuce (*Ulva*) Sampling and Analytical Methods

Ulva was abundant and attached to bottom substrate (mostly attached to large stones and rocks) just beyond the *Spartina* beds at the mid-tide level. It was noted that attached *Ulva* was missing or sparse on the waste rock lying in these areas. Figure 2 presents the five sampling locations where the *Ulva* was collected and composited. Each of the composite samples was collected by hand, placed into a ziplock bag and brought back to the ERT/REAC Biological Laboratory. The *Ulva* was transferred to a sieve to be washed with distilled water, blotted dry, transferred to sampling jars and frozen. Samples were shipped to the subcontract laboratory, homogenized and analyzed for TAL metals, Sn and % of solids.

3.7 Risk Characterization Methods

3.7.1 Hazard Quotient Method

The HQ method (EPA 1997) was employed to compare exposure concentrations to TRVs or BMs based on ecological endpoints such as mortality, reproductive failure, or reduced growth.

This is done using chronic toxicity values derived from the literature that are intended to represent a lower dose over a longer duration of exposure, resulting in subtle effects that would be expected to manifest themselves at the population level over the long term. Both the NOAEL and the Lowest Observable Adverse Effect Level (LOAEL) were used to calculate HQs. The comparison is expressed as a ratio of potential intake values to effect levels, as follows:

$$HQ = \frac{\text{Exposure Concentration (Maximum or Mean)}}{\text{Chronic Effect Level (e.g., NOAEL)}}$$

3.7.2 Hazard Quotients Using Sediment and Surface Water Benchmarks

To determine risk to Assessment Endpoint #1 (Survival, Growth and Reproduction of Intertidal Invertebrate Community) and Assessment Endpoint # 2 (Fecundity and Early-Life Stage Development of the Horseshoe Crab), the concentration of COPCs in sediment, surface water and pore water will be compared to benchmark values. The sediment BMs were derived from the Marine/Estuarine Sediment Screening Guidelines for low and medium effects ranges (ERL and ERM) provided by the NJDEP (1999). The ERL benchmarks represent concentrations at which adverse benthic impacts are observed in approximately 10% of the studies. The ERM benchmarks represent concentrations in which contamination greater than the ERM value is observed in more than 50% of cases studied. Surface water and/or pore water BMs were derived from National Recommended Water Quality Criteria for Seawater (EPA 2002).

For this ERA, the maximum and mean concentrations of the surface water and pore water and the 95% UCL (calculated with Pro UCL) and mean concentrations for the sediments will be compared to the benchmark values. If the resulting HQs are greater than 1.0, it will be concluded that there is risk to the assessment endpoint.

3.7.3 Food Chain Exposure Models

Food chain models were employed for assessing risk to Assessment Endpoints #3 and #4. Four exposure scenarios or models were evaluated for each receptor species. Models 1 and 3 included sediment ingestion plus food ingestion. Models 2 and 4 estimated exposure based on food ingestion but excluded sediment exposure. Water intake was excluded from these models. A comparison between Models 1 and 3 with Models 2 and 4 provided a means of distinguishing if a particular environmental matrix (sediment or food) may be driving risk. The results of these models were used to determine the contamination values that bound the threshold for adverse effects to each assessment endpoint (EPA 1997). A summary of the four exposure models is as follows:

Model 1: used conservative life history parameters, the 95% UCL concentrations of contaminants in sediment, and the maximum site-specific tissue data (*i.e.*, *Ulva* or clam tissue). Conservative life history parameters included the lowest published adult body weight, the highest published ingestion rates for incidental sediment, and the highest published ingestion rates for food.

Model 2: used the same conservative life history parameters as Model 1 but only included exposure to the maximum site-specific tissue data (*i.e.*, *Ulva* or clam tissue). Sediment intake was excluded for this model.

Model 3: used representative life history parameters and mean concentrations of contaminants in sediment and site-specific tissue data (*i.e.*, *Ulva* or clam tissue). Representative life history parameters included the mean (or mid-point of a published range) adult body weight, and the mean (or mid-point of a published range) ingestion rates for incidental sediment along the mean (or mid-point of a published range) ingestion rates for food.

Model 4: used the same representative life history parameters as Model 3 but only included exposure to the mean site-specific tissue data (*i.e.*, *Ulva* or clam tissue). Sediment intake was excluded for this model.

The avian receptor species selected to model AE 3 and 4 via food chain exposure models include:

Assessment Endpoint #3: Invertivorous Shore Birds: Semipalmated plover
Assessment Endpoint #4: Herbivorous Shore Birds: Canada goose

Life histories for the selected receptor species are presented in Appendix C. The receptor species identified should be viewed as surrogates, representative of all species within the feeding guild selected as an Assessment Endpoint. For each receptor, a conservative (lowest body weight, highest ingestion rate) and representative (average body weight and ingestion rate) exposure profile has been developed. For this ERA, an area use factor (AUF) of 1.0 was utilized. The conservative assumptions being the receptors acquire all of their food at the site. Exposure parameters used in the food chain models are presented in Table 5.

The receptors primary food items were analyzed to measure site-specific COPC exposure. It was assumed COPC concentrations in the collected food items were representative of levels in all food items consumed by the receptor.

The TRVs for each COPC were based on studies in the published literature. Appendix B provides the toxicological profiles for the COPCs and Table 4 lists the TRVs. Two TRVs were used to evaluate ecological risk, a NOAEL and a LOAEL. The NOAEL is the highest dose at which adverse effects are not expected to occur in a study, and the LOAEL is the lowest dose at which adverse effects are expected to occur. The exposure concentrations derived from the modeling were entered into the HQ equation, and a HQ was calculated for both the NOAEL and LOAEL. The following assumptions were made:

A contaminant concentration was considered to exceed the threshold and demonstrate model-calculated risk to the given receptor if both the NOAEL-based HQ and LOAEL-based HQ were greater than or equal to 1.0.

If neither the NOAEL- or LOAEL-based HQs were greater than or equal to 1.0, it was concluded that there is no model-calculated risk to the given receptor.

If the NOAEL-based HQ was greater than or equal to 1.0 but the LOAEL-based HQ was not, it was concluded that it could not be determined that there was no model calculated risk.

4.0 ANALYSIS PHASE

The analysis phase is Step 6 of the eight-step Superfund process (EPA 1997). It provides the technical evaluation of existing and potential exposure and ecological effects at the Site based on the information collected during the previous steps. The analysis phase is subdivided into Characterization of Ecosystem (Section 3.1), Characterization of Exposure (Section 3.2) and Characterization of Effects (Section 3.3).

4.1 Characterization of Ecosystem

The intertidal zone along the sea wall is comprised of three zones – upper, mid, and lower. The upper zone is the high tide level consisting of an open sandy beach area with a considerable amount of boulder-size to medium-size waste rock/slag scattered along the entire length of the seawall. The mid zone is characterized with a dense *Spartina* bed which extends for about 10 to 15 feet from the high to mid tide level. The lower zone extends from the mid tide level to the low tide level and is characterized as open sandy surf area mixed with cobble stones, rocks and randomly scattered rock-size slag.

A significant level of sampling was performed within this intertidal zone following the criteria for the selection of the target species provided in Section 3.6. Polychaete worms were one of the target biota expected to be present to meet the criteria. Polychaete worms not only are an important food source for a variety of organisms, but also serve as good biomonitors being directly exposed to metal contaminants associated with the sediments and pore water. However, only five to six small worms, weighing a total of 2.0 grams, were collected from the entire sampling effort. Insufficient biomass of the worms eliminated any assessment of metal bioaccumulation for this biota. Essentially this intertidal zone seemed to be almost devoid of a polychaete worm community. It was noted during the site investigation that local residents were observed collecting worms to be used for bait along the beach area just east of the sea wall. Numerous worms were easily collected by the local residents with the use of a trowel with the largest worms ranging several inches in length. No evidence of these same types of worms was found along the seawall.

The diversity of the invertebrate fauna within the intertidal zone was primarily restricted to two mollusks - ribbed mussel and the long neck clam. These two mollusks plus the hard shell clam collected in the subtidal zone represented the prevalent invertebrate fauna. No other invertebrate fauna was observed to be sufficiently prevalent for the biomonitoring. However, these three mollusks do represent different trophic levels which provided effective means of biomonitoring the bioaccumulation of metal contaminants under different exposure scenarios.

The ribbed mussels, ranging in size from 50 to 80 millimeters (mm), were situated within the *Spartina* beds at high densities (Table 6). These adult ribbed mussels were buried just below the surface of the sediments with portion of the bivalve shell slightly extending above the surface of the sediments allowing their siphon to be extended into the water column for filtering. Most of the *Mya* clams were completely buried in the sediments from just below the surface to depths of six to eight inches. A total of 277 long neck juvenile clams (*Mya*) were collected for the tissue analyses with almost all of the clams (98%) ranging in size between 10 and 30 mm (Table 6). This size range places the clams at an age of less than one year. The largest single clam collected was 40 mm. No adult *Mya* clams were collected. The hard shell clam was found inhabiting the subtidal zone just beyond the intertidal zone. The hard shell clams were buried in the sediment at just below the surface to depths of six to ten inches. A total of 10 hard clams ranging in size from 50 to 90 mm, were collected for the tissue analyses (Table 6). All of the hard shell clams were mature clams that were at least 2 to 4 years old.

Ulva was present at the lower tidal area of the intertidal zone attached to hard sandy substrate and rocks. However, it was interesting to observe that *Ulva* was not attached to the slag boulders or debris that was randomly scattered in this area. *Ulva* is known to be a good bio-indicator of metal contamination in marine ecosystems as described in Sections 3.2.5 and 3.3.1.

An impairment of the invertebrate community within this intertidal zone seems to be supported by the limited invertebrate fauna present. With only two sessile invertebrates prevalent (i.e., ribbed mussel and the *Mya* clams), the presence of only juvenile Mya clams with no adult clams collected and the almost complete absence of a Polychaete community.

4.2 Characterization of Exposure

The Chemical Assessment report for this WA (EPA/ERT/REAC 2009) not only provided a characterization of the slag boulders and the leaching ability of metals from the slag, but also presented the analytical results for pore water, sediment, and the biota including the mollusks (ribbed mussel, hard shell clam and the long-neck clam), macro algae (*Ulva*), and the foraging fish (*Fundulus* sp.). A summary of the sediment, pore water, surface water and biota results are presented below.

4.2.1 Sediment Results

Eleven sediment samples were collected within proximity of the collection sites for the ribbed mussels and the *Mya* clams (Table 7). The sampling locations of these 11 samples are shown in Figure 2. In addition, 18 sediment samples were collected along the seawall during the same time period as this study (September 2008) by Weston Solutions, Inc. (2009) (Table 8). The sampling locations of these 18 samples are shown in Figure 3.

The metal concentrations in the sediment samples along the seawall were highly heterogeneous, analogous to what would be expected within a contaminated landfill site. Lead levels particularly stand out with concentrations ranging from 12 to 5,860 milligrams per kilogram (mg/kg) (Tables 7 and 8). Table 9 summarizes all the sediment data collected from the intertidal zone providing the minimum, mean, maximum and the 95% UCL concentrations. Both the 95% UCL and mean concentrations were used for characterizing risk of all four assessment endpoints.

4.2.2 Pore Water Results

Five pore water samples were collected in the intertidal zone within proximity of the collection sites for the *Mya* (long neck) clams. Table 7 summarizes the results (as micrograms per liter (ug/L)) for both the total metals in unfiltered and filtered samples.

Lead levels in the filtered and unfiltered pore water samples presented different results. Two particularly high Pb values (1,500 ug/L and 2,400 ug/L) were determined for the unfiltered pore water samples. Dissolved Pb values ranged from < 2.0 ug/L to a high value of 170 ug/L. The maximum Sb concentrations in unfiltered pore water were 56 and 270 ug/L and the maximum dissolved Sb concentrations were 19 ug/L and 130 ug/L. Dissolved As levels ranged from 11 to 86 ug/L and total As levels ranged from 19 to 230 ug/L. Total and dissolved Mn levels were quite similar, ranging from 530 ug/L to 2,300 ug/L, indicating Mn in the pore water was essentially as dissolved metal. Copper and Zn concentrations were mostly below detection limits for both the total and dissolved metals (Table 7). Maximum pore water concentrations, as dissolved metals, were used for characterizing risk of Assessment Endpoints 1 and 2.

4.2.3 Surface Water Results

Twelve surface water samples were collected by Weston Solutions Inc. (2009) from the public beach just east of the seawall along the entire length of the seawall within the intertidal zone (Figure 5 in Weston Solutions, Inc 2009). Table 10 provides the analytical results as dissolved metals. The maximum concentrations detected for Sb, As, Cu and Pb were 26.5, 36.2, 82.6 and 1,780 ug/L, respectively. Maximum surface water concentrations as dissolved metals were used for characterizing risk of Assessment Endpoints 1 and 2.

4.2.4 Mollusk Tissue Results

Five composite samples of the long neck clams (*Mya*), six composite samples of the ribbed mussels and three composite samples of the hard shell clams were analyzed for metals. All of the clams were depurated for 24 hours following collection to void the clams of sediments. Analyses were only performed on the soft tissue. The bivalve shells of the mollusks were discarded. Only juvenile *Mya* clams of less than one year were collected from the intertidal zone along the seawall. No adult *Mya* clams were found. Both the ribbed mussel and the hard shell clam composite samples were composed only of adult clams of more than two to four years.

Tissue concentrations of Pb and Cu were highest in the juvenile *Mya* clams compared to either the adult ribbed mussels or the adult hard shell clams (Table 7). Lead levels for the *Mya* clams ranged from 3.4 to 17 mg/kg (mean of 13.1 mg/kg) whereas ribbed mussels had Pb levels ranging from 3.0 to 8.6 mg/kg (mean of 5.0 mg/kg) and the hard shell clam had Pb ranging from 1.7 to 3.1 mg/kg (mean of 2.6 mg/kg). Copper levels for the *Mya* clams ranged from 8.5 to 31 mg/kg (mean of 21.3 mg/kg) whereas Cu levels in ribbed mussels ranged from 10.4 to 16 mg/kg with a mean of 13.5 mg/kg and the Cu levels in the hard shell clams ranged from 11 to 14.3 mg/g with a mean of 13.1 mg/kg (Table 7).

Manganese levels were significantly higher in the *Mya* clams (4.3 to 130 mg/kg) compared with the ribbed mussels (4.4 to 7.1 mg/kg), but were lower than Mn levels in the hard shell clams (52 to 200 mg/kg). Arsenic and Ag levels were comparable between all three mollusks with levels ranging from 1.4 to 9.8 mg/kg for As and 0.15 to 2.1 mg/kg for Ag between all three mollusks. Zinc levels were higher in the *Mya* clams than the ribbed mussels, but within the same range for the hard shell clams (Table 7). Maximum and mean concentrations of the metals accumulating in all the mollusks combined were used for characterizing risk of assessment endpoint 3 (Table 11).

4.2.5 *Ulva* Tissue Results

Five composite samples of *Ulva* collected within the intertidal zone were analyzed for metal concentrations. The *Ulva* bioconcentrated As, Cr, Pb, Mn and Ni at higher levels than other biota including: ribbed mussels, *Mya* clams, hard shell clams and killifish (Table 4). Lead, Mn and Ni concentrations in the *Ulva* are of particular note with concentrations of 24 to 80 mg/kg for Pb, 120 to 280 mg/kg for Mn and 2.6 to 4.7 mg/kg for Ni. Arsenic concentrations in the *Ulva* ranged from 4.7 mg/kg to 15 mg/kg and Cr had 2.6 to 5.0 mg/kg of Cr (Table 7). Maximum and mean concentrations of metals accumulating in Ulva were used for characterizing risk of assessment endpoint 4 (Table 11).

4.2.6 Foraging Fish (*Fundulus* sp.) Tissue Results

Five composite samples of killifish (*Fundulus* sp.) were analyzed for metals. Killifish exposure to the metal contaminants within the intertidal zone would primarily be the result of surface water exposure and foraging as the fish move in and out of the area with the tide. Data was collected for only one sampling area. Arsenic, Cu, Cr, Pb and Ni tissue concentrations in the killifish tissue were lower than measured for the other biota (ribbed mussels, soft shell clam, hard shell clam and *Ulva*) (Table 7). However detectable levels of Pb were found in all fish samples.

4.3 Characterization of Effects

4.3.1 Intertidal Plant Community

The intertidal plant community adjacent to the seawall was dominated by the cordgrass (*Spartina alterniflora*) and the macro algae (*Ulva*). As previously described, *Spartina* beds extended along the entire reach of this intertidal area along the mid-tidal level whereas the *Ulva* were mostly attached to the rocks and bottom substrate along the low tidal level. However, it was noted - the *Ulva* were not attached to the scattered slag boulders in this area of the intertidal zone which may indicate an inhibition for the *Ulva* to grow on the slag.

Several investigators have published on the capability of *Ulva* species as a bio-indicator of metal contamination in marine systems (Baesada *et.al*. 2009, Talbot and Chegwidden 1982, Villares *et.al*. 2005, 2001, 2002, Ho 1990). It has been suggested that both the laminar structure of *Ulva* (providing a high surface area to volume ratio) and its capacity to grow in heavily contaminated areas increases it's potential as a useful bio-indicator. Table 12 provides a comparison of the metals accumulated in *Ulva* species between this study and the literature-based studies. Lead and Mn levels in the *Ulva* for this site ranged at higher concentrations than the literature-based studies. Copper, Ni and Zn levels in the Ulva at this site were at either comparable or lower levels than the literature-based studies (Table 12). This comparison of the metal accumulation in *Ulva* between the literature-based studies and the results from this study does emphasize Pb as the predominant contaminant for this site along with the capability of *Ulva* to bioaccumulate Pb at high levels.

Spartina was not evaluated for its potential to accumulate metals for this WA. However, there are a number of literature-based investigations (Weis *et.al*. 2003, Windhams, *et.al*. 2001, Cambrolle, *et.al*. 2008, Carbonell-Barrachina *et.al*. 1998) that have evaluated the ability of *Spartina* to accumulate metals including As, Cu, Pb and Zn. The metals accumulate in roots, stems, rhizomes and leaves.

The capability of both *Ulva* and *Spartina* to bioaccumulate and/or sequester metals from the abiotic media (sediments, pore water and surface water) within this intertidal zone would suggest that this plant community may, in part, be functioning like plants used in bioremediation for superfund sites, that is, sequestering the metal contaminants into plant tissue. However, in the fall when the *Spartina* and *Ulva* die back, there would be a recycling of the metals accumulated in the plant tissue back into the ecosystem.

4.3.2 Toxicity of Complex Metal Mixtures to Long Neck Clams (*Mya arenaria)*

Juvenile clams can achieve a length of 30 mm by the first year. The acceptable commercial size for these steamer clams is 50 mm which can be achieved in 18 to 24 months. Steamer clams can reach maturity in five years and achieve 150 mm by eight years.

The toxicity of complex metal mixtures to adult *Mya* has been investigated by performing bioassays simulating the concentrations of metals measured within the interstitial pore water of Narragansett Bay, Rhode Island (Eisler 1977). Adult *Mya* clams were exposed to mixtures of metal salts of Mn, Zn, Pb, Cu, Cd and Ni at three different dose levels (none [control], 100% dose [highest levels of metals determined in the interstitial water] and 20% dose [dilution of the 100% dose]). These assessments were performed under winter and summer conditions.

The accumulation of metals in the adult *Mya* clams during the summer studies (Eisler 1977) are presented in Table 13. Nickel, Pb, Cu, Mn and Zn accumulated in the adult *Mya* clams following exposures of 1, 7 and 14 days at the 20% dose and days 1 and 7 at the 100% dose. All of the adult *Mya* clams were dead in the 100% dose by day 12. Metal accumulations in the adult clams for the control in the Eilser study (1997) were comparable to the results from a production shellfish bed of adult clams derived from another study (Pringle et.al. 1969) (See Table 13) with the exception of higher Cu levels for the clams in the shellfish bed.

The results from the Eisler studies (1977) demonstrated that adult *Mya* clams can bioaccumulate environmental levels of Pb, Mn, Zn, Cu, and to a lesser extent, Ni. The results also demonstrated that metal accumulation (as well as mortality), are accelerated at higher temperatures. These studies did not evaluate the bioaccumulation of As nor did these studies assess accumulation and toxicity to juvenile *Mya* clams. A higher sensitivity of metal accumulation to the juvenile clams could be expected.

5.0 RISK CHARACTERIZATION

Step 7 of the eight-step Superfund process (EPA 1997) focuses on the risk characterization which integrates exposure and effects data for estimating risks to the Assessment Endpoints. Each of the following subsections reviews each Assessment Endpoint, the testable hypotheses, measure of effects used to assess risk and concludes with a determination of risk to that Assessment Endpoint.

5.1 Assessment Endpoint #1: Survival, Growth and Reproduction of the Intertidal Invertebrate Community

Risk to the intertidal invertebrate community was determined by comparing the surface water, pore water and sediment concentrations of the metal contaminants within the intertidal zone adjacent to the seawall to acute and chronic toxicity benchmark values. If the metal concentrations in the surface water, pore water or sediments exceeded the sediment or surface water benchmarks (e.g., HQ > 1.0), the intertidal invertebrates would be considered at risk.

For the intertidal sediments, risk calculations were based on metal exposures at 95% UCL concentrations and at mean concentrations using the ERL and the ERM estuarine screening benchmarks (Tables 14 and 15). Risk to the invertebrate community was determined from As and Pb exposures from both the 95% UCL and the mean concentrations exceeding the ERL benchmark. In addition, risk to the invertebrate community was determined from Pb exposures either from the 95% UCL or the mean concentrations using the less conservative ERM benchmarks (Tables 14 and 15).

Risk to the intertidal invertebrate community was determined from pore water exposures based on both chronic and acute toxicity benchmarks. Maximum concentrations of As, Mn and Pb as dissolved metal in the pore water exceeded the chronic seawater quality benchmarks (EPA 2002 AWQC or Ecotox SW 1996) and the maximum concentration for As in the pore water exceeded the acute seawater quality benchmark (EPA 2002 AWQC) (Table 16).

Additionally, risk to the intertidal invertebrate community was determined from surface water exposures based on both chronic and acute toxicity benchmarks. Maximum concentrations of As, Cu and Pb in the surface water as dissolved metal exceeded the chronic seawater quality benchmarks (EPA 2002 AWQC or Ecotox SW 1996) and the maximum concentration for Cu and Pb in the surface water exceeded the acute seawater quality benchmark (EPA 2002 AWQC) (Table 17).

Impairment of the invertebrate community within this intertidal zone was suggested based on several observations during the site investigation. The diversity of invertebrates that were prevalent was limited to two mollusks – adult ribbed mussels and the juvenile *Mya* clams. No adult *Mya* clams were collected. There is the potential that the metals in this environmental media, particularly the sediment and pore water, could be toxic to the *Mya* clams (See Section 3.3.2). In addition, this intertidal zone had a limited polychaete community. The risk calculations for surface water, pore water and sediment further supports an impairment of the intertidal invertebrate community.

5.2 Assessment Endpoint #2: Fecundity and Early-Life Stage Development of the Horseshoe-Crab

Risk to the fecundity and early-life stage development of the horseshoe crab is based on the same risk characterization parameters and calculations as defined for Assessment Endpoint #1, that is, comparing the surface water, pore water and sediment concentrations of the metal contaminants within the intertidal zone to acute and chronic toxicity benchmark values (Tables 14 and 15).

The intertidal zone at this Site provides the type of habitat to which adult horseshoe crabs would migrate within the Raritan Bay to develop shallow nests along the sandy beach areas for the purpose of laying and fertilizing eggs. Not only is the development of the embryos at risk but also the subsequent development of the larval and juvenile stages of the horseshoe crab are at risk from exposure to the metals, particularly for As and Pb, in the surface water, pore water and sediments within this intertidal zone of this Site. As in the intertidal invertebrate community, fecundity and early-life stage development of the horseshoe crab are at risk

5.3 Assessment Endpoint #3: Survival, Growth and Reproduction of the Invertivorous Shore Birds

For this Assessment Endpoint, dietary exposures were modeled using the semipalmated plover as the receptor species. Four exposure scenarios were used in the models. Food intake was based on the mollusk concentrations (*Mya* clam, ribbed mussel and hard shell clam) derived from on-site collections. Appendix C provides the food chain models. Table 18 summarizes the HQs based on Models 1 to 4.

Model 1 used conservative life history parameters and the 95% UCL concentrations of COPCs in sediment and maximum concentrations in site-specific tissue data of the mollusks. Model 2 used the same conservative life history parameters as Model 1, but only included exposure to the site-specific tissue data. Model 1 indicated model-calculated risk to the invertivorous shore birds from exposure to As and Pb. It could not be concluded there was no calculated risk to the invertivorous shore birds from exposure to Cr. When Model 2 was calculated without the sediment exposure, it could not be concluded there was no calculated risk to the invertivorous shore birds from exposure to Pb in the mollusks, indicating the sediment, and not the food intake, was driving risk for this Assessment Endpoint (Table 18).

Model 3 used representative life history parameters and the mean concentrations of COPCs in sediment and in site-specific mollusk tissue. Model 4 used the same representative life history parameters as Model 3, but only included exposure to the site-specific tissue data. Model 3 indicated model-calculated risk to the invertivorous shore birds from exposure to Pb and it could not be concluded there was no calculated risk to invertivorous shore birds from exposure to As and Cr. When Model 4 was calculated without the sediment exposure, it could not be concluded there was no calculated risk to the invertivorous shore birds from exposure to As and Pb based on the food intake of the mollusks (Table 18).

A TRV for acute toxicity was derived for the invertivorous shore birds using the semipalmated plover as the receptor (Appendix B). This acute TRV is based on the high incidental ingestion rates for sediment which is characteristic of shore birds while feeding. A sediment concentration of 3,600 mg/kg d.w. was calculated to being acutely toxic to 50% of the plovers and a sediment concentration of 2,370 mg/kg d.w. was acutely toxic to 20% of the plovers. Given the 95% UCL and maximum Pb concentrations for the intertidal zone along the seawall of 1,098 mg/kg and 5,860 mg/kg, respectively, the acute TRVs (ranging from 2,370 to 3,600 mg/kg) are within the range and risk from acute toxicity may exist for the invertivorous shore birds.

5.4 Assessment Endpoint #4: Survival, Growth and Reproduction of the Herbivorous Shore Birds

For this Assessment Endpoint, dietary exposures were modeled using the Canada goose as the receptor species. Four exposure scenarios were used in the models. Food intake was based on the *Ulva* (macro algae) concentrations derived from on-site collections. Appendix C provides the food chain models. Table 19 summarizes the HQs based on Models 1 to 4.

Model 1 used conservative life history parameters and the 95% UCL concentrations of COPCs in sediment and maximum concentrations in site-specific *Ulva* tissue. Model 2 used the same conservative life history parameters as Model 1, but only included exposure to the site-specific tissue. Model 1 indicated model-calculated risk to herbivorous shore birds from exposure to As, Cr and Pb. When Model 2 was calculated without the sediment exposure, it could not be concluded there was no calculated risk to herbivorous shore birds from exposure to Pb in the *Ulva*, indicating sediment, and not the food intake, was also driving risk for this assessment endpoint. Model 3 and 4 used representative life history parameters and the mean concentrations of COPCs in sediment and/or in site-specific mollusk tissue. When Models 3 and 4 were calculated, it could not be concluded there was no calculated risk to herbivorous shore birds from exposure to Pb (Table 19).

6.0 UNCERTAINTY ANALYSIS AND ASSUMPTIONS

Uncertainties and limitations are inherent in all risk assessments and need to be considered when interpreting results. Knowledge of the sources of uncertainty, the direction of the uncertainty, how the ERA dealt with these sources of uncertainty, and an understanding on the magnitude of effects resulting from the sources of uncertainty allows for informed management decisions. The nature and magnitude of uncertainties depend on the amount and quality of data available, the degree of knowledge concerning the site conditions, and the assumptions made to perform the assessment. Within this ERA, decisions regarding the direction of uncertainty were made to drive the uncertainty in one direction, towards a more conservative conclusion (higher risk estimate). The uncertainties and assumptions related to the SLERA, problem formulation, exposure characterization, effects characterization, and risk characterization are discussed in the following sections.

It must be recognized that this ERA considered only TAL metals as potential contaminates of concern. This decision was based upon existing information on the waste material present and existing data on the Site.

6.1 Screening-Level Ecological Risk Assessment

The SLERA, (presented in Section 2) evaluated exposures of metals through surface water, pore water and sediment. There are several factors inherent in the SLERA processes which require assumptions which need to be considered when interpreting results.

Conservative estuarine/marine sediment and surface water benchmark values were used to ensure potential ecological threats were not overlooked. The benchmarks used consisted of chronic NOAELs or the highest exposure concentrations for which ecological effects are not observed. There is the assumption that the most sensitive receptor organisms and life stages are exposed.

The maximum media concentrations available were used for exposure values for each contaminant and this exposure was assumed to be present throughout the entire sampling area. It was further assumed this maximum exposure was encountered at the predicted concentration all of the time.

A HQ less than 1.0 does not indicate a lack of risk, but suggests that there is a high degree of confidence that minimal risk exists for the given contaminant, particularly given that benchmark values are based on the lowest measurable concentration considered to be protective of the most sensitive organism in the soil medium.

The bioavailability of each contaminant was assumed to be 100%. In addition, there is the assumption that the chemical form of the metal at the Site is the same as that from the literature toxicology study. Since toxicology studies are conducted on the most toxic forms of a chemical, this assumption also increases the conservative nature of the ERA.

6.2 Problem Formulation – Focused ERA

There are several sources of uncertainty within the problem formulation phase of the ERA. These include: issues related to use of existing data; the selection of assessment endpoints; assumptions within the site conceptual model, and the input parameters for the exposure and toxicity characterization.

Data used in this ERA were based on samples collected in September 2008 not only under this WA, but also the sediment and surface water samples that were collected by Weston Solutions, Inc (2009) along the entire reach of the intertidal zone adjacent to the seawall during the same time period.

As described in Section 3.6, the sampling design incorporated a biomonitoring approach, collecting organisms whose contaminant levels could be linked to the Site and would be expected to accumulate the contaminants. However, there was a limitation of what organisms could be collected due to only a few organisms which were prevalent for tissue analyses. Target organisms which would have been preferred, but were not found at the site included polychaetes and adult *Mya* clams. Only juvenile *Mya* clams were found for tissue determinations. In addition to the juvenile *Mya* clams, ribbed mussels, hard shell clams, killifish, and Ulva were also collected for bioaccumulation determinations and potential use within dietary exposure models. Organisms were collected along the seawall area of the site in close proximity to known contamination. Collection of organisms at alternate locations could yield different results.

The selection of appropriate assessment endpoints and the receptors models which will serve to characterize risk is a critical step within the problem formulation of an ERA. As noted, this ERA focused upon selected assessment endpoints. The selection of assessment endpoints was done considering the habitats present at the site and knowledge of the environmental fate, transport and toxicology of metals (particularly Pb, Cu and zinc) in an estuarine intertidal area. A full ERA would be expected to expand the number of assessment endpoints evaluated, for completeness.

6.3 Characterization of Exposure

The uncertainties associated with exposure characterization include: total exposure estimations; exposure pathways not retained for quantitative evaluation; identification of ecological receptors; selection of representative species; exposure route assumptions; and fate and transport of contaminants.

The site conceptual model presents the pathways by which contaminants are released from source areas exposing receptors. However, some exposure pathways are difficult to evaluate or information does not exist to allow for a quantitative evaluation of exposure from particular exposure pathways. Within this ERA, dermal and water intake exposure pathways are not evaluated. It is believed these exposure pathways are not substantive relative to the other exposure pathways (e.g., food intake and sediment ingestion).

Exposure to metals in the sediment, pore water, surface water and biota was based on maximum and/or 95% UCL and/or mean concentrations measured. Utilization of these upper boundary exposure estimates would be expected to overestimate risk.

Within this ERA, the selection of receptor model species was done with the intent of selecting a species expected to be at the high end (most exposed) of the exposure distribution for the group of organisms represented by the assessment endpoint. The exposure may be a result of the food ingestion rate, the estimate of incidental soil/sediment ingestion and/or the preferred forage of the model species. The uncertainty associated with the selection of species models is done with the intent of not underestimating the exposure to other species within the assessment endpoint.

It is important to note that the exposure estimates for avian assessment endpoints did not include the potential for ingestion of lead particles as grit. Many birds, including waterfowl, ingest gravel sized particles as grit; the ingestion of lead shot by waterfowl and the associated adverse effects is well documented. Since particulate lead has been observed at the jetty area, there is a potential for this exposure pathway to be complete, however a formal assessment and characterization of the risk from particulate lead was not conducted here.

Life history data (Appendix C and Table 5) for shore bird receptors was based primarily on literature-derived data for species known to inhabit or utilize the region of this study area. However, exposure parameters may be based either on data from the same species from different areas or modeled based on allometric relationships (e.g., food ingestion rates). Uncertainty is introduced from the use of literature-based values for sediment and food ingestion rates, dietary compositions, and body weights. However, as noted above the selection of model input parameters is done such that the resulting exposure model should not underestimate the exposure to organisms within the assessment endpoint.

For the AUF, which is the foraging area utilized by the receptor, a factor of 1.0 was applied. An AUF of 1.0 assumes 100% of the exposure occurs at the exposure point concentration. For these high-end exposure scenarios, the exposure value for each contaminant used in the risk calculations was assumed to be present throughout the foraging area of the receptor and encountered at the predicted concentration and does not incorporate the local or seasonal movement patterns of some species. This application of AUF of 1.0 should overestimate the actual risk to the receptors. However, wildlife also tend to focus their foraging for periods of time; this behavior may result in exposures approaching those modeled using an AUF of 1.

Another assumption is the contaminants in food items were assumed to exhibit 100% absorption efficiency, and were assumed not to be excreted during the life of the receptor. That is, the risk estimated from dietary exposure is based on administered dose, not absorbed dose. Absorption efficiency or bio-assessability is complex and is a function of the chemical form of the metal (EPA 2007). For this reason an assumption of 100% absorption efficiency is believed to be a conservative assumption.

Dietary ingestion information was obtained from the literature for the receptor species. However, simplifications of complex diets were performed to utilize site specific tissue and sediment data. In some cases, food ingestion rates were based on information for a similar species or were calculated from an allometric equation. It was assumed these estimated ingestion rates were representative of the true ingestion rates for the receptor species in question

There is very little information available in literature regarding rates of incidental soil/sediment ingestion for wildlife species. The incidental soil/sediment ingestion rates used within this ERA are presented in Appendix C. Where appropriate, within each life history profile an incidental soil/sediment ingestion rate is developed. These ingestion rates were developed to be reasonable but also not result in an underestimate of exposure. There are documented instances of very high incidental ingestion rates under specific conditions. However, these unique situations do not appear to exist at the Raritan Bay Slag Site. As noted above, it should be noted that the use of hard particles for grit by avian receptors is not included within the incidental ingestion term.

All of the mollusks (*i.e*., ribbed mussels, hard shell clams and *Mya* clams) and foraging fish (*Fundulus* sp) were depurated over a 24-hour period following collection to allow sediment to be voided from the digestive system. There is an uncertainty that 24 hour depuration is the most appropriate for all organisms; it is a standard depuration time to facilitate an accurate determination of the contaminant levels actually within the tissues of an organism. For exposure models to receptors which consume the depuration species, incidental soil/sediment ingestion terms are added into the exposure model.

The food chain models used simplified diets of one item with a static ingestion rate. In reality, each receptor organism's diet is varied, and the ingestion rate varies with food availability and metabolic needs (such as during growth of young and periods of metabolic stress). While reliance on a single forage item is not realistic over long time periods or even a growing season, it may not be implausible, within the shorter time frames, relevant to the toxic mechanism of the contaminants. Organisms do not use the environment uniformly, but rather forage where food is most readily available, which can be the area of contamination. Also, organisms may focus on particular food items as they become available, such as when macro algae or other marsh plants become available during their growing seasons. For this reason, use of a single food item was selected so potential for under-estimating exposures is believed to be low.

Information concerning speciation of inorganic COPCs (metals) was generally lacking. It is widely recognized that bioavailability and toxicity can vary dramatically as a function of the speciation and/or partitioning of COPCs (EPA 2007). As a consequence, there is uncertainty with respect to the exposure and hazard assumptions. However, given the toxicological studies used to generate the TRVs for this ERA generally used bioavailable/toxic forms of the contaminants, it is unlikely risk is underestimated.

6.4 Characterization of Effects

Benchmark values selected for surface water and sediments were derived from the most current criteria, guidance, or technical data available. Benchmarks were based on the more conservative value of the available published literature which would not pose an adverse effect to insure that risk was not underestimated. Also, alternative benchmark values (e.g. acute toxicity benchmarks) were applied in this ERA to assess the potential magnitude of risk to the assessment endpoints.

For sediments both the ERL and ERM benchmarks were applied at both the 95%UCL and mean exposure concentrations of the metals. For surface water and pore water, acute and chronic toxicity benchmarks were applied.

Not all TRVs for the birds (Appendix B) represent the same degree of certainty. TRVs were mostly derived from laboratory animal studies. The extrapolation between species from different taxa may induce error because of differences in pharmacokinetics, representative organs, and population variability. TRVs were selected through a systematic process to minimize the potential for under-estimating the toxicity of contaminants to the assessment endpoints. A literature search was conducted to determine the chronic toxicity of the contaminants of concern when ingested by the indicator species. If no toxicity values could be located for the receptor species, values reported for a closely related species were used. All studies were critically reviewed to determine whether study design and methods were appropriate. When values for chronic toxicity were not available, median lethal dose (LD_{50}) values were used. For the purpose of this ERA, a factor of 10 was used to convert the reported LD_{50} to a LOAEL. A factor of 10 was also used to convert a reported LOAEL to a NOAEL. When several toxicity values were reported for a receptor species, the most conservative value resulting in an ecologically significant adverse effect was used in risk calculations, regardless of toxic mechanism. Toxicity values obtained from long-term feeding studies were used in preference to those obtained from single dose oral studies. No other safety factors were incorporated into this ERA.

Uncertainty is also related to estimates of effects (e.g., NOAELs, LOAELs, LD_{50}s) which have inherent variability. These values are statistically determined and are reflective of the experimental design. For example within a particular toxicity study, the reported LOAEL and/or NOAEL are dependent upon exposure levels selected within the study design. It is not known within these studies how much lower the LOAEL may be or how much higher the NOAEL may be. However, within risk calculations this error is believed to be relatively minor as compared to other sources of error within the risk calculations of the ERA.

In some cases, contaminant doses in the diet were reported as ppm. These were converted to a daily intake in milligrams per kilogram body weight (BW) per day (mg/kg BW/day). This conversion allows dietary toxicity levels cited for one species to be converted to a daily dose for a different species based on body weight.

Error can be introduced by use of invalid assumptions in the conceptual model. Conservative assumptions were made in light of the uncertainty associated with the risk assessment process. This was done to minimize the possibility of concluding no risk is present when a threat actually does exist (i.e., to eliminate false negatives). Whenever possible, risk calculations were based on conservative values. For example, LOAELs used to calculate HQs were the lowest values found in the literature, regardless of toxic mechanism.

6.5 Risk Characterization

This ERA evaluates exposure to contaminants through food and sediment ingestion and/or uptake. Major sources of uncertainty include natural variability, error, and insufficient knowledge. Natural variability is an inherent characteristic of ecological receptors, their stressors, and their combined behavior in the environment. Biotic and abiotic parameters in these systems may vary to such a degree that the exposure of similar ecological receptors in the same system may differ temporally and spatially. Factors contributing to temporal and spatial variability include differences in individual organism behavior (within a species), changes in the weather or ambient temperature, unanticipated interference from other stressors, interactions with other species in the community, differences between microenvironments, and numerous other factors.

An HQ of less than 1.0 may not indicate a lack of risk, but suggests there is a high degree of confidence that minimal risk exists for the given contaminant, since benchmark values are based on the lowest measured concentration considered to be protective of the most sensitive organism in a medium.

Risk to assessment endpoints 3 and 4 was evaluated from food chain modeling incorporating exposure to contaminants through food and incidental sediment ingestion. Four food chain models were run. Model 1 was the most conservative and would be expected to overestimate risk for these Assessment Endpoints. Model 3 was the least conservative model and could possibly be expected to underestimate risk for these Assessment Endpoints.

Selection of representative receptor species for assessment endpoints 3 and 4 (semipalmated plover for invertivorous shore birds and Canada goose for herbivorous shore birds) to characterize risks was based on known site-specific species. Semipalmated plover are known to have high sediment ingestion rates. It is one of the smaller plovers which would utilize this site and would not be expected to underestimate risk. The Canada goose was used as the receptor for herbivorous birds, although Brandt are observed to more frequently utilize and forage at the site. However, life history parameters are not readily available for Brandt, but are available for the Canada goose. It is not known if Brandt would be more or less sensitive to the metal contaminants than the Canada goose.

This ERA evaluates exposure to contaminants through food and sediment ingestion. Major sources of uncertainty include natural variability, error, and insufficient knowledge. Natural variability is an inherent characteristic of ecological receptors, their stressors, and their combined behavior in the environment. Biotic and abiotic parameters in these systems may vary to such a degree that exposure of similar ecological receptors in the same system may differ temporally and spatially. Factors contributing to temporal and spatial variability include differences in individual organism behavior (within a species), changes in the weather or ambient temperature, unanticipated interference from other stressors, interactions with other species in the community, differences between microenvironments, and numerous other factors.

7.0 SUMMARY OF RESULTS

Results from this effort are presented in two separate documents. The first document is Chemical Assessment Report (EPA/ERT/REAC 2009) presenting data collected, an interpretation of data relative to nature, fate and transport of the metal contaminants related to slag boulders and debris associated with the seawall and Cheesequake Creek Jetty. This document presents an initial ERA, providing assessment of the impact of metals being released and transported from the slag boulders and debris to the biological communities inhabiting and or utilizing the intertidal zone adjacent to the seawall.

The Chemical Assessment Report (EPA/ERT/REAC 2009) provides a characterization of the slag boulders originating from the seawall and the Cheesequake Creek Jetty. The slag boulders were characterized as being highly heterogeneous with a wide range of concentrations at particularly high concentrations for As, Cu, Pb, Sb, Sn and Zn. Slag boulders often had concentrations of these metals exceeding 1,000 mg/kg to 10,000 mg/kg to 100,000 mg/kg. Lead concentrations exceeded 10,000 mg/kg for 10 of the 17 slag samples analyzed and exceeded 100,000 mg/kg for 5 of the 17 samples analyzed. Speciation of the metal compounds in the slag boulders was determined and reinforced the conclusion of heterogeneity of the material present confirming it was metallurgical waste material. The analyses identified various Pb, Cu, As and Sn compounds as dominant. Five different Pb types were identified as dominant types in the slag boulders.

The Chemical Assessment Report (EPA/ERT/REAC 2009) also reported on the leaching ability and/or mobility of the metals from the slag boulders based on two different types of evaluations. One evaluation assessed the leaching ability of metals under acidic conditions following Toxicity Characteristic Leaching Procedure (TCLP) methods. Leachable Pb exceeded 1,000 mg/kg for 15 of the 17 slag samples, with 10 samples having leachable Pb concentrations exceeding 10,000 mg/kg. All 17 slag samples exceeded the Resource Conservation and Recovery Act (RCRA) regulatory limit for Pb based on TCLP, designating the slag boulders as hazardous waste. The other evaluation assessed the leaching ability and/or mobility of the metals from the slag boulders using neutral salt solution. Particularly high levels of Pb were determined to be leachable and/or mobilized from this neutral salt exposure with higher levels of leachable Pb in the interior (non-weathered) samples compared with the exterior layer of the slag boulders. This finding supports the conclusion: contaminants within the slag material are leachable and therefore able to be released into the environment under normal conditions at the Site.

Sediment, pore water and surface water collected along the intertidal zone adjacent to the seawall had high metal concentrations consistent with the conclusion: the slag boulders are releasing metals. Sediments along the entire length of the intertidal zone adjacent to the seawall are characterized as having a high spatial variability, with a wide range of concentrations, particularly for Pb, Sb, As and Cu (Tables 8 and 9). Pore water was analyzed for dissolved metals and total metals. High concentrations of Pb, Mn, As and Sb were measured in the unfiltered samples. Additionally, high concentrations of Mn, Pb As, and Sb were measured for several of the filtered samples as dissolved metals (Table). Likewise, high concentrations of Sb, As, Cu and particularly Pb as dissolved metals were measured in the surface water (Tables 7 and 10). The wide variation of contaminant concentrations in sediments, pore water and surface water is consistent with influence of Site characteristics. Findings of elevated pore water and surface water concentrations is of particular importance as this data supports a conclusion that Site contaminants are being released into the environment.

The intertidal zone adjacent to the seawall provides the appearance of a typical coastal marsh grass (*Spartina*) ecosystem. Shore birds, including Brandt and Canada geese grazing on either the *Ulva* or *Spartina*, plovers searching for invertebrates and killideer nesting, are common observations within this intertidal zone. However, an impairment of this intertidal ecosystem was indicated based field observations of the invertebrate community during the site investigation. This intertidal ecosystem immediately adjacent to the seawall supported a limited invertebrate fauna with only two sessile invertebrates prevalent, that is, adult ribbed mussels and juvenile *Mya* or steamer clams. All of the juvenile *Mya* clams were less than one-year old with no adult clams found. In addition, only a limited Polychaete community was found, such that the proposed collection of these organisms could not be completed.

The intertidal plant community of this ecosystem was dominated by two plants (*Spartina* and the macro algae *Ulva*) growing along the entire reach adjacent to the seawall. *Ulva* was selected to biomonitor the accumulation of metals into plant tissue. Arsenic, Cr, Pb, Mn and Ni accumulated in *Ulva* at higher levels than in mollusks. This accumulation of metals in the *Ulva* would lead to the expectation that the roots, stems and leaves of the *Spartina* would also contain contaminants. The bioaccumulation of Site related metals in the biota at the levels observed confirms the release of these contaminants from Site waste material, as suggested by the laboratory leaching data.

The ERA conducted here, follows Superfund guidance, and utilized a systematic approach for selecting hazard and exposure parameters incorporating the selection of both conservative and more representative (less conservative) inputs for risk calculations. The conservative inputs for risk calculations serve to reduce the chance of underestimation of risk to the assessment endpoints, while the more representative, less conservative, inputs assesses the potential of increased risk to the Assessment Endpoints. An overview of some of the conservative and less conservative inputs are:

- Risk to the intertidal invertebrate community and early life-stage development of the horseshoe crab (Assessment Endpoints 1 and 2) was based on total exposure of metals in the pore water, surface water and sediments. Total exposure for estimating risk of the metals in pore water and surface water was based on maximum concentrations as dissolved metals compared to both chronic toxicity and acute toxicity benchmarks. Total exposure for estimating risk of the metals in sediments was based on 95% UCL and mean concentrations compared to low effects and mid-effects chronic toxicity benchmark values.

- Risk to invertivorous and herbivorous shore birds (Assessment Endpoints 3 and 4) was based on model-calculated dietary exposures utilizing conservative life history parameters (lowest body weight, highest ingestion rates), maximum dietary concentrations and 95% UCL sediment concentrations for Model 1 and 2. Models 3 and 4, which utilized less conservative (representative) life history parameters, was determined based on mean dietary and sediment concentrations.

This ERA characterized risk to four Assessment Endpoints within this intertidal ecosystem, as follows:

- Risk to the intertidal invertebrate community was characterized based on exposures of metals in sediments, pore water and surface water. Chronic toxicity benchmarks were exceeded from measured exposure concentrations of As and Pb in the sediment (Tables 14 and 15), from measured As, Mn, and Pb exposures in pore water (Table 16) and from measured As, Cu and Pb exposures in surface water (Table 17). In addition, the intertidal invertebrate community is at risk based on acute toxicity benchmarks from measured exposure concentrations of As in pore water and measured Cu and Pb exposures in surface water (Table 16 and 17). Given the fact that calculated risk is based on both acute and chronic benchmarks relative to mean, 95%UCL and/or maximum exposure concentrations, calculated risk to this intertidal invertebrate community is not overestimated. As previously discussed, impairment of the intertidal zone based on low diversity of invertebrate fauna and absence of certain fauna and life-stages further supports these risk conclusions.

- Fecundity and Early-life Stage Development of the Horseshoe Crab are at risk based on the same risk calculations for As, Pb, and Cu exposures in sediment, pore water and surface water which characterized risk to the intertidal invertebrate community. Adult horseshoe crabs are known to come ashore in the bays of Monmouth and Middlesex Counties including Raritan Bay to construct shallow nests within the intertidal zone, lay and fertilize their eggs. Development of the embryos and the larval stages of the horseshoe crab are at risk from metal contamination in sediments, pore water and surface water within this intertidal zone.

- Risk to the invertivorous shore birds was characterized based on dietary exposure models using the semipalmated plover as the receptor species (Table 18). Model calculated risk indicated that As and Pb in the sediments was driving risk based on the most conservative model using the 95% UCL sediment exposures and the maximum food (mollusks) intake exposures. It could not be concluded that there was no calculated risk from exposure to Cr based on the most conservative model. When the more representative dietary exposure models were applied using the mean sediment and mean food intake exposures, risk was being driven by Pb. In addition, the invertivorous shore birds may be at risk based on acute exposure to Pb. Acute TRVs for Pb derived for the semipalmated plover are within the same range as the 95%UCL and maximum concentrations of Pb measured in the sediments within the intertidal zone.

- Risk to the herbivorous shore birds was characterized based on dietary exposure models using the Canada goose as the receptor species (Table 19). Model calculated risk indicated As, Cr and Pb in sediments was driving risk based on the most conservative model using the 95% UCL sediment exposures and the maximum food (*Ulva*) intake exposures. It could not be concluded there was no calculated risk from exposure to Pb when representative dietary exposure models were applied.

In addition, the presence of elemental lead particles (especially at the jetty area) and particles of waste material may pose a risk to all avian receptors. This risk would be the result of ingestion of particle for use within the bird crop, the same mechanism of exposure which occurs from the ingestion of lead pellets by waterfowl. No attempt was made to quantify this risk for the Site.

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Table 1. Hazard Quotients (HQs) Based on Maximum Concentrations of COPCs in Surface Water
Raritan Bay Slag Site
Middlesex County, NJ

COPC	Maximum Concentration	Benchmark Value (BM)[a]	HQ	Retained as COPC?	Rationale
	ug/L	ug/L			
Antimony	26.5	nb	nb	Yes	nb
Arsenic	36.2	36	1.0	Yes	HQ>1
Copper	82.6	3.1	26.6	Yes	HQ>1
Lead	1,780	8.1	220	Yes	HQ>1

COPC - Contaminant of Potential Concern
a - EPA 2002 AWQC SW chronic BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
AWQC SW chronic BMs- Ambient Water Quality Criteria for Seawater - Chronic benchmark values
HQ - Hazard Quotient
nb - no benchmark available
Shaded rows = HQ>1 or nb
ug/L - micrograms per liter
BM - Benchmark

Table 2. Hazard Quotients (HQs) Based on Maximum Concentrations of COPCs in Pore Water
Raritan Bay Slag Site
Middlesex County, NJ

COPC	Maximum Concentration	ecotox SW BM[a]	EPA 2002 AWQC SW chronic BM[b]	HQ	Retained as COPC?	Rationale
	ug/L	ug/L	ug/L			
Antimony	130	nb	nb	nb	Yes	nb
Arsenic	86	nb	36	2.4	Yes	HQ>1
Chromium VI	7.1	50	50	0.1	No	HQ<1
Copper	<40 (U)	2.4	3.1	ND	Yes	RL>BM
Lead	170	8.1	8.1	21.0	Yes	HQ>1
Manganese	2300	80	nb	28.8	Yes	HQ>1
Nickel	7.3	8.2	8.2	0.9	No	HQ<1
Silver	<2 (U)	nb	nb	nb	Yes	nb
Tin	<200 (U)	nb	nb	nb	Yes	nb
Zinc	<20(U)	81	81	< 1.0	No	HQ<1

COPC - Contaminant of Potential Concern
b - EPA 2002 AWQC SW chronic BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
a. - Ecotox SW - US EPA OSWER (Ofiice of Solid Waste and Emergency Response) 1996. Eco Update Ecotox Thresholds, Washington D.C. EPA 540/F-95/038
AWQC SW chronic BMs- Ambient Water Quality Criteria for Seawater - Chronic benchmark values
HQ - Hazard Quotient
nb - no benchmark available
ug/L - micrograms per liter
U - Undetected
Shaded rows = HQ>1 or nb or RL>BM
RL>BM - Analytical Reporting Limit greater than benchmark value
BM - Benchmark

Table 3. Hazard Quotients (HQs) Based on Maximum Concentrations of COPCs in Sediment
Raritan Bay Slag Site
Middlesex County, NJ

COPC	Maximum Concentration	Benchmark Value (BM)[a]	HQ	Retained as COPC?	Rationale
	mg/kg d.w.	mg/kg d.w.			
Antimony	33.2	nb	nb	Yes	nb
Arsenic	29	8.2	3.5	Yes	HQ>1
Chromium	57	81	0.7	No	HQ<1
Copper	117	34	3.4	Yes	HQ>1
Lead	5,860	47	124.7	Yes	HQ>1
Manganese	260	nb	nb	Yes	nb
Nickel	18.4	21	0.9	No	HQ<1
Silver	1.1	1	1.1	Yes	HQ>1
Zinc	242	150	1.6	Yes	HQ>1

COPC - Contaminant of Potential Concern
a - NJ SW sed ERLs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999.
Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Low (ERL).
Shaded rows = HQ>1 or nb or RL>BM
BM - Benchmark
HQ- Hazard Quotient
mg/kg d.w. - milligrams per kilogram dry weight
nb - no benchmark available

Table 4. Toxicity Reference Values (TRVs) for Birds*
Raritan Bay Slag Site
Middlesex County, NJ

Analyte	Birds	
	NOAEL	LOAEL
	mg/kg BW/day	
Metals		
Antimony	NA	NA
Arsenic	1.6	2.3
Chromium	1	5
Copper	26.9	33.2
Lead	1.5	15
Manganese	977	9770
Nickel	57.2	79
Silver	3.97	39.7
Tin	NA	NA
Zinc	55.4	118.4

NA - no studies available
NOAEL - No Observed Adverse Effect Level
LOAEL - Lowest Observed Adverse Effect Level
mg/kg BW/day= milligrams per kilogram body weight per day
* See Appendix A for derivation of TRVs to be used for the dietary exposure models

Table 5. Life History Exposure Parameters for Food Chain Model Receptor Species
Raritan Bay Slag Site
Middlesex County, NJ

Receptor	Scenario	Body Weight (kg)	Total Ingestion (kg/day dw)	Food Ingestion (kg/day dw)	Water Ingestion L/day	Soil/Sediment Ingestion (kg/day dw)	Home Range ha	Assumed Dietary Composition (%)		
								animal	plant	invert.
Semipalmated Plover	Conservative	0.0322	0.00754	0.00528	0.0059	0.00226	0.01	0	0	100
	Representative	0.0498	0.01356	0.01125	0.0078	0.00231	0.142	0	0	100
Canadian Goose	Conservative	0.95	0.213	0.051	0.057	0.162	290	0	100	0
	Representative	3.29	0.148	0.1467	0.131	0.00128	1,560	0	100	0

kg = kilograms
kg/day dw = kilograms per day dry weight
ha = hectares
invert.=invertebrate
% = percent

Table 6. Size and Weight of Mollusk Samples
Raritan Bay Slag Site
Middlesex County, NJ

	Composite Sample #	No. of Clams per Composite	Size range of clams (mm)	Total weight of Clams with Bivalve Shell (gm)	Total weight of Clam Tissue without Bivalve Shell (gm)
Soft Shell Clam (*Mya*)	Mya-1	53	15 to 25	40.1	21.5
	Mya-2	106	15 to 25	66.3	37.7
	Mya-3	5	30 to 40	46.8	27.9
	Mya-4	34	10 to 25	34.2	19.3
	Mya-5	79	10 to 30	66.8	43
Ribbed Mussels	RM-1	10	70 to 80	303.1	164.7
	RM-2	11	50 to 80	221.5	121.6
	RM-3	8	65 to 75	201	110.6
	RM-4	12	50 to 65	218.1	117.7
	RM-5	11	50 to 65	158.5	85.7
	RM-6	12	40 to 60	97.9	56.3
Hard Shell Clam (*Mercenaria*)	Mer-1 (Small)	4	50 to 60	149	30.4
	Mer-2 (Medium)	3	60	203.4	37.5
	Mer-3 (Large)	3	75 to 90	475.6	93.9

mm- millimeter
gm- grams

Table 7. Analytical Results of Biota, Sediment and Pore Water Samples Collect
Raritan Bay Slag Site
Old Bridge Townnship, NJ

Sample Description	Sample Location	Units	Antimony (Sb)		Arsenic (As)		Copper (Cu)		Chromium (Cr)		Lead (Pb)	
			Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier
Pore Water	PW-A1 (Total/Unfiltered)	ug/L	4	U	20	U	80	U	12	U	8	U
	PW-B1 (Total/Unfiltered)	ug/L	2	U	19		40	U	7.6		10	
	PW-C1 (Total/Unfiltered)	ug/L	56		71		40	U	9.8		1500	
	PW-D1 (Total/Unfiltered)	ug/L	270		230		91		17		2400	
	PW-E1 (Total/Unfiltered)	ug/L	9.7		39		40	U	7.9		160	
	PW-A2 (Filtered)	ug/L	2	U	11		40	U	6		4	U
	PW-B2 (Filtered)	ug/L	2	U	23		20	U	6.6		2	U
	PW-C2 (Filtered)	ug/L	19		41		20	U	6.6		2	U
	PW-D2 (Filtered)	ug/L	130		86		40	U	7.1		170	
	PW-E2 (Filtered)	ug/L	4		29		20	U	6.4		2	U
Sediment Samples	SS-RM1	mg/kg	0.22		5.6	J	4.4	J+	9		12	
	SS-RM2	mg/kg	0.31		6.1	J	9.9	J+	9.5		16	
	SS-RM3	mg/kg	0.49		8.5	J	15		21		19	
	SS-RM4	mg/kg	1.5		6.9	J	11		7.7		94	
	SS-RM5	mg/kg	6.1		13	J	22		18		660	
	SS-RM6	mg/kg	1.6		29	J	17		46		93	
	SS-MM1	mg/kg	1.1		9.4	J	13		15		47	
	SS-MM2	mg/kg	0.84		15	J	11		37		29	
	SS-MM3	mg/kg	1.2		5.4	J	31		14		83	
	SS-MM4	mg/kg	0.42		12	J	9.4	J+	44		26	
	SS-MM5	mg/kg	0.47		7.4	J	7.4	J+	11		24	
Ribbed Mussels	RM-1	mg/kg	0.23	U	7.7		14	J+	2.3		3	
	RM-2	mg/kg	0.24		7.6		16	J+	2		5.1	
	RM-3	mg/kg	0.23		6.1		10.4		1.8		3.3	
	RM-4	mg/kg	0.21	U	7.7		14	J+	2.1		4	
	RM-5	mg/kg	0.19	U	7.7		12	J+	1.3		6	
	RM-6	mg/kg	0.25		9.5		14.4	J+	1.6		8.6	
Soft Shell Clam (*Mya*)	Mya-1	mg/kg	0.15	U	1.4		8.5	J+	0.67		3.4	
	Mya-2	mg/kg	0.4		7.6		21		1.6		15	
	Mya-3	mg/kg	0.37		6.4		22		1.6		17	
	Mya-4	mg/kg	1.2		7.3		31		3.1		16	
	Mya-5	mg/kg	0.33		7.2		24		1.5		14	

Hard Shell Clam (*Mercenaria*)	Mer-1 (Small)	mg/kg	0.11	U	5.1		14		1.8		1.7	
	Mer-2 (Medium)	mg/kg	0.11	U	5.9		11		1.6		2.9	
	Mer-3 (Large)	mg/kg	0.1	U	9.8		14.3		1.2		3.1	
Foraging Fish (*Fundulis*)	FF-1	mg/kg	0.17	U	3.6		5	J+	1		0.52	J+
	FF-2	mg/kg	0.19	U	3.5		4.8	J+	1		0.92	J+
	FF-3	mg/kg	0.16	U	3.5		5.9	J+	0.98		0.49	J+
	FF-4	mg/kg	0.17	U	3.8		6.1	J+	1.1		0.49	J+
	FF-5	mg/kg	0.29	U	3.7		5	J+	1.3		0.52	J+
Sea Lettuce (*Ulva*)	Ulva-1	mg/kg	0.23		4.7		12	J+	5		24	
	Ulva-2	mg/kg	0.6		15		9.7	J+	2.6		56	
	Ulva-3	mg/kg	0.54		10		11	J+	2.8		66	
	Ulva-4	mg/kg	0.57		12		12	J+	4.6		69	
	Ulva-5	mg/kg	0.75		6.3		13	J+	3.4		80	

mg/kg=milligram per kilogram dry weight
ug/L=microgram per liter

U=Undetected
J+= Value is estimated high

J= Estimated
UJ= Not detected and reporting limit is estimated

Manganese (Mn)		Nickel (Ni)		Silver (Ag)		Tin (Sn)		Zinc (Zn)	
Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier
840		9.6		4	U	400	U	40	U
540		6.9		2	U	200	U	20	U
1800		10		2	U	200	U	27	
1100		33		2	U	200	U	150	
2300		5.8		2	U	200	U	20	U
840		7.3		2	U	200	U	20	U
530		4.9		2	U	200	U	20	U
1800		6.1		2	U	200	U	20	U
1100		11		2	U	200	U	20	U
2300		5.5		2	U	200	U	20	U
22	J	1.6	J+	0.11	U	11	UJ	25	
44	J	3		0.095	U	9.5	UJ	31	
48	J	2.6		0.089	U	8.9	UJ	33	
28	J	2.3	J+	0.08		8	J	40	
260	J	5.8		0.19		18	J	57	
99	J	8.5		0.12		9.9	UJ	91	
29	J	5		0.13		8.7	J	68	
56	J	6.6		0.1	U	10	UJ	91	
19	J	2.9		1.1		14	UJ	53	
55	J	4.9		0.099	U	9.9	UJ	56	
32	J	2.8		0.087	U	8.7	UJ	44	
5.3	J+	0.54	J+	0.76		23	U	57	
4.7	J+	0.63	J+	0.71		21	U	64	
4.4	J+	0.57	J+	0.38		14	U	41	
6.3	J+	0.62	J+	0.52		21	U	57	
5	J+	0.45	J+	0.48		19	U	53	
7.1	J+	0.54	J+	0.38		21	U	59	
4.3	J+	0.36	J+	0.15	U	15	U	21	
30		1.3	J+	0.38		27	U	94	
130		1.3	J+	0.7		16	U	96	
20		1.4	J+	0.5		12	U	86	
21		1.7	J+	0.52		13	U	94	

52		1.4	J+	0.19		11	U	69	
200		0.95	J+	0.26		11	U	93	
120		1.6	J+	2.1		10	U	120	
13.3		0.34	J+	0.17	U	17	U	80	
18		0.39	J+	0.19	U	19	U	93	
14		0.33	J+	0.16	U	16	U	79	
17		0.39	J+	0.17	U	17	U	93	
15		0.38	J+	0.29	U	29	U	87	
120	J-	2.6	J+	0.19	U	19	U	32	
230	J-	4	J+	0.23	U	23	U	51	
250	J-	4.7	J+	0.18	U	18	U	41	
280	J-	3.4	J+	0.2	U	20	U	51	
280	J-	3.6	J+	0.21	U	21	U	38.1	

Table 8. Sediment Data*(mg/kg d.w.) Collected in the Intertidal Zone Along Seawall
Raritan Bay Slag Site
Middlesex County, NJ

Sample Location	Distance from	Antimony (Sb)		Arsenic (As)		Copper (Cu)		Chromium (Cr)		Lead (Pb)		Manganese (Mn)		Nickel (Ni)		Silver (Ag)		Tin (Sn)		Zinc (Zn)	
	Seawall (ft)	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier	Concentration	Qualifier
SS-RM1		0.22		5.6	J	4.4	J+	9		12		22	J	1.6	J+	0.11	U	11	UJ	25	
SS-RM2		0.31		6.1	J	9.9	J+	9.5		16		44	J	3		0.095	U	9.5	UJ	31	
SS-RM3		0.49		8.5	J	15		21		19		48	J	2.6		0.089	U	8.9	UJ	33	
SS-RM4		1.5		6.9	J	11		7.7		94		28	J	2.3	J+	0.08		8	J	40	
SS-RM5		6.1		13	J	22		18		660		260	J	5.8		0.19		18	J	57	
SS-RM6		1.6		29	J	17		46		93		99	J	8.5		0.12		9.9	UJ	91	
SS-MM1		1.1		9.4	J	13		15		47		29	J	5		0.13		8.7	J	68	
SS-MM2		0.84		15	J	11		37		29		56	J	6.6		0.1	U	10	UJ	91	
SS-MM3		1.2		5.4	J	31		14		83		19	J	2.9		1.1		14	UJ	53	
SS-MM4		0.42		12	J	9.4	J+	44		26		55	J	4.9		0.099	U	9.9	UJ	56	
SS-MM5		0.47		7.4	J	7.4	J+	11		24		32	J	2.8		0.087	U	8.7	UJ	44	
RBS-SED17	75		R		R		R	4.9		75.7			R	1.3	J	1.4	U	14.2	UJ	27.6	J
RBS-SED18	75		R		R		R	8.3		186			R	2.7	J	1.6	U	16	UJ	52.7	J
RBS-SED07	25		R		R		R	57		5860			R	18.4		0.24	J	127	J	242	J
RBS-SED08	25		R		R		R	7.1		861			R	3	J	1.3	U	38.6	J	46.3	J
RBS-SED19	75		R		R		R	9.1		93.5			R	3.2	J	1.5	U	15	UJ	43.2	J
RBS-SED09	25		R		R		R	17.3		403			R	2.7	J	1.2	U	14.5	J	47	J
RBS-SED20	75		R		R		R	19.6		58.2			R	7.4		1.5	U	15.2	UJ	59.2	J
RBS-SED21	75		R		R		R	5.7		48.1		17.4	17.4	1.2	J	1.3	U	13.1	UJ	32.2	J
RBS-SED22	75	7.7	UJ	2.4		8.4		6.4		53.6	J	18.7		5.2	U	0.32	J	12.9	UJ	34.9	
RBS-SED10	25		R		R		R	7.4		326			R	3.2	J	1.2	U	12.4	UJ	41.1	J
RBS-SED23	75	8.6	UJ	3.1		9.6		5.5		90.7	J	17.2		5.7	U	0.22	J	14.3	UJ	30.3	
RBS-SED11	25		R		R		R	8.1		441			R	4.4	J	1.4	U	47.8	J	53.8	J
RBS-SED24	75	8.3	UJ	2.9		9.7		6		79.4	J	14.6		5.5	U	1.4	U	13.8	UJ	32.9	
RBS-SED12	25		R		R		R	10.4		660			R	5.8		1.2	U	53.6	J	54.9	J
RBS-SED25	75	13.9	J	6.6		21.2		4.5		458	J	15.5		4.7	U	1.2	U	22.5		29.1	
RBS-SED26	25	20.5	J	15.7		25.4		6.3		525	J	89.5		5.6	U	1.4	U	1020		39.4	
RBS-SED88	75	28	J	19.2		117		5.8		1440	J	13.7		5.6	U	0.14	J	42.1		53.2	
RBS-SED87	25	33.2	J	22.5		37.3		6.7		1100	J	51.6		12.2		0.23	J	45.4		41.1	

* Data Derived from This Study and Weston Solutions, Inc Report (2009)
U= Undetected analyte
J= Estimated concentration
UJ - The analyte was not quantifiable at or above the Contract Required Quantitation Limit (CRQL), or QA/QC requirements were not me
R= Unusable value
mg/kg d.w. - milligrams per kilogram dry weight

Table 9. Summary of Analytical Results (mg/kg d.w.) of Sediment Data* Along the Intertidal Zone Adjacent to Seawall
Raritan Bay Slag Site
Old Bridge Township, NJ

	Number of Valid Samples	Minimum Concentration Detected	Maximum Concentration Detected	Mean Concentration	95% UCL Concentration
Antimony (Sb)	18	0.22	33.2	7.3	30.9
Arsenic (Ar)	18	2.4	29	10.6	14.2
Copper (Cu)	18	4.4	117	21.1	30.3
Lead (Pb)	29	12	5,860	478	1,098
Manganese (Mn)	19	13.7	260	29	70.2
Silver (Ag)	29	0.1	1.1	0.3	0.3
Tin (Sn)	29	8	1,020	120	127
Zinc (Zn)	29	25	242	53	67

mg/kg d.w. - milligrams per kilogram dry weight
95% UCL - 95 percent upper confidence level
* Sedimment data derived from this WA and the Samples collected by Weston Solutions, Inc 2009.

Table 10.Surface Water Results* as Dissolvved Metals Collected from Intertidal Zone Adjacent to Seawall
Raritan Bay Slag Site
Middlesex County, NJ

		RBS-SW01		RBS-SW02 DUP		RBS-SW03		RBS-SW04		RBS-SW05		RBS-SW06		RBS-SW07		RBS-SW08		RBS-SW09		RBS-SW10		RBS-SW11		RBS-SW18	
	Analyte	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier	Result	Qualifier
Dissolved	Antimony (Sb)	2.6	J	1.4	J	60	U	1.6	J	60	U	60	U	5.9	J	4.3	J	15.3	J	19.4	J	**26.5**	J	60	U
	Arsenic (As)	10	U	10	U	10	U	10	U	10	U	10	U	11.2		10	U	24.5		**36.2**	J	27.1		10	U
	Copper (Cu)	25	U	25	U	25	U	25	U	25	U	25	U	8.9	J	3.1	J	21.6	J	**82.6**	J	35.2		25	U
	Lead (Pb)	37.8	J	24.8	J	24.9		31.3	J	11.9	J	17.7	J	152		89.7		686		**1780**	J	739		10	U

All surface water results are in micrograms per liter (ug/L)
J- Estimated concentration
U- Analyte not detected
UJ- The analyte was not quantifiable at or above the Contract Required Quantitation Limit (CRQL), or QA/QC requirements were not met
* Results derived from Figure 5 in Weston Solutions, Inc. 2009 Report

Table 11.Summary of Metal Concentrations (mg/kg d.w.) in *Ulva* and Mollusks*
Raritan Bay Slag Site
Middlesex County, NJ

COPC	*Ulva*		Mollusks*	
	Maximum Concnetration	Mean Concentration	Maximum Concnetration	Mean Concentration
Antimony (Sb)	0.8	0.5	0.4	0.3
Arsenic (Ar)	15.0	9.6	9.8	6.9
Copper (Cu)	13.0	11.5	31.0	16.2
Chromium (Cr)	5.0	3.7	3.1	1.7
Lead (Pb)	80.0	59.0	17.0	7.4
Manganese (Mn)	280.0	232.0	130.0	43.6
Silver (Ag)	U	U	2.1	0.6 **
Tin (Sn)	U	U	U	U
Zinc (Zn)	51.0	42.6	120.0	71.7

* Mollusks includes ribbed mussels, *Mya* clams, and hard shell clam
mg/kg d.w. - milligrams per kilogram dry weight
U - all samples were below the quantification limit
** - avaerage excludes single non detect value

Table 12. Metal Accumulation in *Ulva* species form Literature-based Studies (ug/g dry weight)
Raritan Bay Slag Site
Old Bridge Township, NJ

Study	Species	Location	Site description	# of Samples	Other Information	Copper (Cu)	Lead (Pb)	Manganese (Mn)	Nickel (Ni)	Zinc (Zn)
1	*Ulva*	Laurence Harbor, Old Bridge Township, NJ	Ulva-1	1		12	24	120	2.6	32
			Ulva-2	1		9.7	56	230	4	51
			Ulva-3	1		11	66	250	4.7	41
			Ulva-4	1		12	69	280	3.4	51
			Ulva-5	1		13	80	280	3.6	38.1
2	*U. rigida*	Spain			range of values	3.05-3.15	1.00-1.05			5.6-6.1
3	*U. lactuca*	Australia	U (near James Point)			6.5	1.7	10.6		44.4
			V			6.6	0.9	2.1		24.7
			W			4.6	0.4	1.9		30.4
			X (in Indian Ocean)			9.3	0.2	1.7		28.3
4	*Ulva spp.*	Spain	Reference		median metal concentrations	20.3	3.2		11.9	25.6
			Contaminated			27.9	3.4		21.3	18.3
5a*	*Ulva*	Galicia		282	range of values	2.2-20.6		4.6-512	0.0-16.2	7.0-66.8
5b	*U. lactuca*	Jordan	Spring		value with standard error	42.1±1.8		24.5±2.4		51.0±4.1
	U. lactuca	Hong-Kong	Clean (winter to spring)		value with standard error	16±2		53±10	8±0.4	27±2
			Polluted			38±5		211±51	15±1.5	66±5
	U. lactuca	Cuba	Polluted		range of values	6.2-11.1		6.7-9.0		10.2-19.9
	U. reticulata	India			reported concentration	13.9		1721	39.1	8.9
	U. fasciata					6.7-7.3		111.3-1076	7.0-9.6	2.8-23.8
	U. lactuca	Sweden	Clean		mean concentration (range of values)	9.5 (1.7-12.3)			2.0 (0.6-7.7)	77.6 (50.6-90.6)
			Intermediate			21.8 (4.8-38.7)			10.0 (6.5-13.4)	90.7 (19.2-162.1)
	U. lactuca	Norway	Polluted		range of values	9-170				20-360
	U. lactuca	S.W. Iberian peninsula	Spring		range of values	5.5-26				59-160
	U. fasciata	S. Brazil			median metal concentrations	9.0		1600	7.8	55.5
	Ulva sp.	S. Australia	Polluted			1.5±0.3				24±8
	U. lactuca	Bosphorus	Polluted (Autumn and winter)		range of values	13.1-24.8		11.4-24.4	9.0-16.8	31.2-66.9
	U. fasciata	S. Brazil	Polluted (Spring)		value with standard deviation	4.0±0.1				42.7±4.2
	U. rigida	Croatia	Polluted (Autumn)		median metal concentrations	8		125		81
	U. lactuca	Greece	Polluted (Annual cycle)		mean concentration (range of values)	7.8 (3.0-22.4)			6.5 (3.2-17.8)	30.0 (7.9-113.6)
	U. fasciata	S. Brazil	Clean (Annual cycle)		mean concentration (range of values)	4.5 (2.0-10.2)				21.6 (4.7-80.2)
	U. rigida	Greece	Polluted (Annual cycle)		mean concentration (range of values)				3.9 (1.1-7.4)	
	U. rigida	Greece	Polluted (Annual cycle)		value with standard error	2.2±0.2				57.3±2.9
	U. rigida	N. Turkey	Summer and Autumn		range of values	4.5-5.7		25.8-28.4		6.0-11.9
	Ulva sp.	Galicia	Summer		mean concentration (range of values)	90.2 (3.6-962)		66.8 (8.6-518)	17.1 (3.9-96.9)	30.5 (6.2-77.7)
	U. lactuca	Argentina	Clean (Autumn)		value with standard deviation	5.5±0.4				5.2±0.3
			Clean			4.2±0.3				2.0±0.4
6a	*Ulva*	N.W. Spain	1st population (summer)		median metal concentrations	5.9			1.6	17
			2nd population (summer)			10.2			1.8	20.8
			1st population (winter)			11.1			2.7	28.0
			2nd population (winter)			14.6			6.2	40.1
6b	*Ulva*	N.W. Spain	Summer			4.7			1.2	14.3
			Winter			9.3			2.1	25.1
7a	*U. lactuca*	Cape D'Aguilar, Hong Kong	January	2	mean concentration (range of values)	10 (9-12)	6 (5-8)	11 (9-13)	7 (4-10)	23 (8-38)
			February	4		10 (6-14)	8 (6-11)	15 (8-22)	8 (4-10)	20 (17-26)
			March	2		14 (14-15)	6 (6-6)	10 (8-12)	8 (7-8)	21 (16-26)
			April	6		9 (5-12)	8 (5-13)	13 (6-26)	7 (5-9)	14 (11-19)
			May	3		13 (11-18)	6 (4-8)	22 (12-28)	6 (5-7)	19 (11-32)
	U. lactuca	Lei Yue Mun, Hong Kong	February	2	median concentration (range of values)	70 (40-99)	19 (14-24)	206 (205-208)	16 (12-19)	45 (43-47)
			March	2		93 (86-100)	12 (12-13)	168 (165-171)	35 (24-46)	42 (38-47)
			April	5		54 (34-77)	21 (11-54)	175 (56-282)	27 (16-40)	53 (31-105)
			May	2		84 (35-132)	16 (10-23)	210 (49-370)	30 (12-48)	100 (89-110)
			June	1	reported concentration	60	17	222	28	56
7b	*U. lactuca*	South Hong Kong	BWB	10	mean value with standard error of the mean	24±2	7±1	33±4	9±1	25±3
			SOH	24		13±1	6±0	12±2	6±0	18±2
			CD	19		11±1	7±1	15±2	7±1	19±2
			TC	13		8±1	9±1	60±16	8±1	22±2
			SMB	10		11±2	10±1	58±16	9±1	33±7
			CHK	1		9	8	11	6	15
			SB	8		10±1	10±2	59±12	9±1	24±2
			MB	14		15±2	12±2	128±62	11±2	47±7
			RB	14		17±2	10±1	63±13	8±1	33±5
			DWB	9		21±3	13±2	95±26	8±1	30±5
			Mean			14	9	53	8	27
	U. lactuca	Southwest Hong Kong	PCW	1	mean value with standard error of the mean	35	7	33	6	25
			WF	16		19±2	8±1	64±14	9±1	29±2
			Mean			27	8	49	8	27
	U. lactuca	Northwest Hong Kong	KTW	1	mean value with standard error of the mean	21	21	81	10	77
			KTE	5		14±2	23±2	75±25	12±1	68±5
			WA	6		19±3	13±1	183±34	12±3	42±8
			BP	3		65±9	30±5	700±59	23±6	71±9
			QP	3		27±9	19±2	386±27	16±5	60±3
			Mean			29	21	285	15	64
	U. lactuca	North Hong Kong	H	4	mean value with standard error of the mean	44±8	62±8	92±21	12±2	52±7
			WC	1		14	9	57	11	82
			KI	5		33±7	20±3	152±23	12±1	48±4
			CB	1		51	89	206	12	102
			Mean			36	45	127	12	71
	U. lactuca	Northeast Hong Kong	NP	2	mean value with standard error of the mean	54±8	166±9	316±4	19±3	70±9
			AKN	5		40±6	24±2	100±29	11±1	61±8
			LYM	12		69±9	18±2	188±25	27±4	58±8
			Mean			54	69	201	19	63

Study 1- Laurence Harbor Site
Study 2- V. Besada et al. / *Journal of Marine Systems* 75 (2009) 305-313
Study 3- V. Talbot and A. Chegwidden / *Aust. J. Mar. Freshw. Res.* 33 (1982) 779-788
Study 4- R. Villares et al. / *Estuaries* 28 (2005) 948-956
Study 5a*- R. Villares et al. / *Hydrobiologia* 462 (2001) 221-232 (Table 3)
Study 5b- R. Villares et al. / *Hydrobiologia* 462 (2001) 221-232 (Table 4)
Study 6a- R. Villares et al. / *Environmental Pollution* 119 (2002) 79-90 (Table 5)
Study 6b- R. Villares et al. / *Environmental Pollution* 119 (2002) 79-90 (Table 6. Background levels calculated for different metals in *Ulva*)
Study 7a- Y.B. Ho./ *Hydrobiologia* 203 (1990) 73-81 (Table 2)
Study 7b- Y.B. Ho./ *Hydrobiologia* 203 (1990) 73-81 (Table 3)

Table 13. Bioaccumulation of Metals by *Mya C* lams Between Literature-based Studies and Raritan Bay Slag Site
Raritan Bay Slag Site
Middlesex County, NJ

	Juvenile *Mya* Clams (<1 yr old)	**Adult *Mya* Clams**						
Metal	Raritan Bay Slag Site	Pringle et al. Study (1968)	R. Eisler Study (1977)					
			Controls	20% mixture			100% mixture	
				1 day	7 days	14 days	1 day	7 days
Arsenic	0.99	nd	nd	nd	nd	nd	nd	nd
Nickel	0.22	0.27	0.28	0.26	0.49	0.24	0.48	0.84
Lead	2.2	0.7	0.74	0.93	2.49	5.74	3.32	17.86
Copper	4.0	5.8	1.36	1.26	1.68	5.09	3.06	13.9
Manganese	16.9	6.7	6.1	17.2	82.28	76.0	51.8	45.72
Zinc	12.5	17.0	11.22	13.08	59.42	82.8	43.36	113.7

nd- not determined

Eisler, R. 1977. Toxicity Evaluation of a Complex Metal Mixture to the Softshell Clam Mya arenaria. Marine Biology 43: 265-276.

Pringle, B.H., Hissong, D.E., Katz, E.L., and Mulawka, S.T. 1968. Trace Metal Accumulation by Estuarine Molluscs. J. Sanit. Engin. Div. Am. Soc. Civ. Engrs. 94 SA3: 455-475.

Table 14. Hazard Quotients for Sediment-Dwelling Organisms Based on 95% UCL Sediment Concentrations Using Low Effect and Medium Effect Benchmarks
Raritan Bay Slag Site
Middlesex County, NJ

	95% UCL Sediment Conc. mg/kg d.w.	NJ SW sed ERLs Low Effects Range mg/kg d.w.	HQ	NJ SW sed ERMs Medium Effects Range mg/kg d.w.	HQ
Antimony	30.9	nb	nb	nb	nb
Arsenic	14.2	8.2	**1.7**	70	0.2
Copper	30	34	0.9	270	0.1
Lead	1,098	47	**23.4**	218	**5.0**
Manganese	70.2	nb	nb	nb	nb
Silver	0.3	1	0.3	3.7	0.1
Zinc	67	150	0.4	410	0.2

NJ SW sed ERLs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999. Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Low (ERL).

NJ SW sed ERMs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999. Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Medium (ERM).

HQ- Hazard Quotient
mg/kg d.w. - milligrams per kilogram dry weight
nb - no benchmark available
95% UCL - 95 percent upper confidence level
Values in "bold" have HQs greater than 1.0

Table 15. Hazard Quotients for Sediment-dwelling Organisms Based on Mean Sediment Concentrations Using Low Effect and Med
Raritan Bay Slag Site
Middlesex County, NJ

	Mean Sediment Conc. mg/kg d.w.	NJ SW sed ERLs Low Effects Range mg/kg d.w.	HQ	NJ SW sed ERMs Medium Effects Range mg/kg d.w.
Antimony	7.3	nb	nb	nb
Arsenic	10.6	8.2	**1.3**	70
Copper	21.1	34	0.6	270
Lead	478	47	**10.2**	218
Manganese	29	nb	nb	nb
Silver	0.3	1	0.3	3.7
Zinc	53	150	0.4	410

NJ SW sed ERLs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999. Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Low (ERL).

NJ SW sed ERMs - NJDEP(New Jersey Department of Environmental Protection) Site Remediation Program. June 1999. Guidance for Sediment Quality Evaluations: Marine/Estuarine Sediment Screening Guidelines; Effect Range Medium (ERM).

HQ- Hazard Quotient
mg/kg d,w, - milligrams per kilogram dry weight
nb - no benchmark available
Values in "bold" have HQs greater than 1.0

HQ
nb
0.2
0.1
2.2
nb
0.1
0.1

Table 16. Hazard Quotients (HQs) for Dissolved Metals in Pore Water Based on Acute and Chronic Benchmarks
Raritan Bay Slag Site
Middlesex County, NJ

	Maximum Pore Water Concentration	ecotox SW	EPA 2002 AWQC SW chronic BM	HQ	EPA 2002 AWQC SW acute BM	HQ
	ug/L	ug/L	ug/L		ug/L	
Antimony	130	nb	nb	nb	nb	nb
Arsenic	86	nb	36	**2.4**	69	**1.2**
Copper	<40 (U)	2.4	3.1	ND	4.8	ND
Lead	170	8.1	8.1	**21.0**	210	0.8
Manganese	2300	80	nb	**28.8**	nb	nb
Silver	<2 (U)	nb	nb	nb	1.9	<1.0
Tin	<200 (U)	nb	nb	nb	nb	nb

EPA 2002 AWQC SW chronic BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
EPA 2002 AWQC SW acute BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
Ecotox SW - US EPA OSWER (Ofiice of Solid Waste and Emergency Response) 1996. Eco Update Ecotox Thresholds, Washington D.C. EPA 540/F-95/038
AWQC SW chronic BMs- Ambient Water Quality Criteria for Seawater - Chronic benchmark values
AWQC SW Acute BMs - Ambient Water Quality Criteria for Seawater - Acute benchmark values
HQ - Hazard Quotient
nb - no benchmark available
Values in "bold" have HQs greater than 1.0
ug/L - micrograms per liter
U - Undetected

Table 17. Hazard Quotients (HQs) for Dissolved Metals in Surface Water Based on Acute and Chronic Benchmarks
Raritan Bay Slag Site
Middlesex County, NJ

	Maximum Surface Water Concentration	ecotox SW	EPA 2002 AWQC SW chronic BM	HQ	EPA 2002 AWQC SW acute BM	HQ
	ug/L	ug/L	ug/L		ug/L	
Antimony	26.5	nb	nb	nb	nb	nb
Arsenic	36.2	nb	36	**1.0**	69	0.5
Copper	82.6	2.4	3.1	**26.6**	4.8	**17.2**
Lead	1,780	8.1	8.1	**220**	210	**8.5**

EPA 2002 AWQC SW chronic BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
EPA 2002 AWQC SW acute BMs- EPA 2002. National Recommended Water Quality Criteria. EPA 822-R-02-047
Ecotox SW - US EPA OSWER (Ofiice of Solid Waste and Emergency Response) 1996. Eco Update Ecotox Thresholds, Washington D.C.
EPA 540/F-95/038
AWQC SW chronic BMs- Ambient Water Quality Criteria for Seawater - Chronic benchmark values
AWQC SW Acute BMs - Ambient Water Quality Criteria for Seawater - Acute benchmark values
HQ - Hazard Quotient
nb - no benchmark available
Values in "bold" have HQs greater than 1.0
ug/L - micrograms per liter
U - Undetected

Table 18. Summary of Hazard Quotients for Invertivorous Shore Birds
Raritan Bay Slag Site
Middlesex County, NJ

Invertivorous Shore Bird: Semiplamated Plover

	Model 1		Model 2		Model 3		Model 4	
	Conservative Life History Parameters 95% UCL Sediment Concentrations Maximum Clam Concentration		Conservative Life History Parameters Sediment Excluded Maximum Clam Concentration		Representative Life History Parameters Mean Sediment Concentrations Mean Clam Concentration		Representative Life History Parameters Sediment Excluded Mean Clam Concentration	
COPC	HQ	HQ	HQ	HQ	HQ	HQ	HQ	HQ
	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL
Antimony	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	1.00	1.40	0.54	0.78	0.89	1.29	0.68	1.00
Chromium	0.47	2.33	0.10	0.51	0.21	1.07	0.08	0.38
Copper	0.22	0.27	0.15	0.19	0.14	0.17	0.11	0.14
Lead	5.32	53.23	0.19	1.86	1.59	15.89	0.11	1.11
Manganese	0.00	0.07	0.00	0.06	0.00	0.03	0.00	0.03
Silver	0.00	0.03	0.00	0.02	0.00	0.04	0.00	0.03
Tin	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	0.17	0.37	0.13	0.28	0.16	0.34	0.14	0.29

HQ less than 1.0
HQ between 1.0 and 10
HQ greater than 10

COPC = Contaminant of Potential Concern
HQ = Hazard Quotient
LOAEL = Lowest Observable Adverse Effect Level
NOAEL = No Observable Adverse Effect Level
ND = Not Determined

Table 19. Summary of Hazard Quotients for Herbivrous Shore Birds
Raritan Bay Slag Site
Middlesex County, NJ

Herbivorous Shore Bird: Canadian Goose

	Model 1		Model 2		Model 3		Model 4	
	Conservative Life History Parameters 95% UCL Sediment Concentrations Maximum *Ulva* Concentration		Conservative Life History Parameters Sediment Excluded Maximum *Ulva* Concentration		Representative Life History Parameters Mean Sediment Concentrations Mean *Ulva* Concentration		Representative Life History Parameters Sediment Excluded Mean *Ulva* Concentration	
COPC	HQ	HQ	HQ	HQ	HQ	HQ	HQ	HQ
	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL
Antimony	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	1.40	2.02	0.35	0.05	0.19	0.27	0.19	0.27
Chromium	1.00	4.69	0.05	0.27	0.03	0.17	0.03	0.16
Copper	0.18	0.22	0.02	0.03	0.02	0.02	0.02	0.02
Lead	12.77	127.70	0.29	2.86	0.19	1.88	0.18	1.75
Manganese	0.00	0.07	0.00	0.04	0.00	0.03	0.00	0.03
Silver	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Tin	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	0.12	0.26	0.02	0.05	0.02	0.03	0.02	0.03

HQ less than 1.0
HQ between 1.0 and 10
HQ greater than 10

COPC = Contaminant of Potential Concern
HQ = Hazard Quotient
LOAEL = Lowest Observable Adverse Effect Level
NOAEL = No Observable Adverse Effect Level
ND = Not Determined

APPENDIX A: CONTAMINANT FATE AND TRANSPORT

A.1 Antimony

Antimony (Sb) is a silvery white metal of medium hardness and low solubility in water. It is found at very low levels in the environment. Metallic Sb is stable under ordinary conditions and is not readily altered by air or water. Antimony displays four oxidation states, Sb^{-3}, Sb^{0}, Sb^{+3}, and Sb^{+5}. The trivalent (Sb^{+3}) state is the most stable and common (ATSDR 1991).

The speciation and physicochemical state of Sb are important to its behavior in the environment and availability to biota. Antimony that is incorporated into mineral lattices is inert and unlikely to be bioavailable. Unfortunately, most analytical methods for Sb do not distinguish between this form and adsorbed forms. Little is known about the adsorption of Sb in soil; however, since Sb forms anionic species, adsorption should be greatest under weakly acidic conditions. Antimony's adsorption to soil and sediment is primarily correlated with iron (Fe), manganese (Mn), and Al content; it coprecipitates with hydroxylated oxides of these elements (ATSDR 1991).

As a natural constituent of soil, Sb is transported into streams and waterways from natural weathering of soil and anthropogenic sources. It has a low occurrence in ambient waters. Antimony in aerobic freshwater and seawater is largely in the +5 oxidation state. Trivalent Sb is the dominant oxidation state in anaerobic water. Antimony can be reduced and methylated by microorganisms in anaerobic sediment, releasing volatile methylated Sb compounds into the water (ATSDR 1991).

Antimony does not appear to bioconcentrate appreciably in fish or other aquatic organisms. Much of the Sb occurring in plants has been found to be a result of surface deposition. Uptake of Sb from soil by plants is reported to be minor. Body burden analyses of terrestrial organisms suggest that biomagnification of Sb does not occur from lower to higher trophic levels (ATSDR 1991).

ATSDR (Agency for Toxic Substances and Disease Registry). 1991. *Toxicological Profile for Antimony*. Report prepared by the Research Triangle Institute for the U.S. Department of Health and Human Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA.

A.2 Arsenic

Arsenic (As) has four valence states (-3, 0, +3, and +5), rarely occurring in its free state in nature. It is usually a component of sulfidic ores, occurring as arsenides and arsenates, along with As trioxide, a weathering product of arsenides. Biotransformations may occur, resulting in volatile arsenicals that normally are returned to land where soil adsorption, plant uptake, erosion, leaching, reduction to arsines, and other processes occur. Inorganic As is more mobile than organic As, and thus poses greater problems by leaching into surface waters and groundwater. The trivalent As^{+3} species are generally considered to be more toxic, more soluble, and more mobile than the pentavalent (As^{+5}) species (Eisler 1988).

Arsenic in water exists primarily as a dissolved ionic species. Particulates account for less than one percent (%) of the total measurable As. Arsenates are more strongly adsorbed to sediments than other As forms. In bodies of water that become stratified in summer, As released from sediment accumulates in the hypolimnion until turnover, when it is mixed with epilimnetic waters. This mixing may result in a 10 to 20 % increase in As concentrations (Eisler 1988).

Eisler (1988) reports the following points: (1) As may be absorbed by ingestion, inhalation, or through permeation of the skin or mucous membrane, (2) cells accumulate As by using an active transport system normally used in phosphate transport, (3) arsenicals are readily absorbed after ingestion, most being rapidly excreted in the urine during the first few days, (4) the toxicity of arsenicals conforms to the following order from greatest to least toxicity: arsines > inorganic arsenites > organic trivalent compounds (arsenoxides) > inorganic arsenates > organic pentavalent compounds > arsonium compounds > elemental As, (5) solubility in water and body fluids appear to be directly related to toxicity, and (6) the mechanisms of arsenical toxicity differ considerably among As species, although signs of poisoning appear similar for all arsenicals.

The primary mechanism of inorganic As^{+3} toxicity is through reaction with sulfhydryl groups of proteins and subsequent enzyme inhibition; inorganic As^{+5} does not react as readily with sulfhydryl groups. Inorganic As^{+3} interrupts oxidative metabolic pathways and sometimes cause morphological changes in liver mitochondria. Methylation greatly reduces the toxicity of inorganic As (both As^{+3} and As^{+5}) and is usually the major detoxification mechanism (Eisler 1988).

The mechanism of organic As toxicity begins with its initial metabolism to the trivalent arsenoxide form, followed by its subsequent reaction with sulfhydryl groups of tissue proteins and enzymes, to form an arylblis (organylthio) arsine. This form inhibits oxidative degradation of carbohydrates and decreases cellular adenosine triphosphate (ATP) (Eisler 1988).

Eisler, R. 1988. Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. *U.S. Fish and Wildlife Service Biological Report*, 85(1.12). 92p.

A.3 Chromium

Chromium (Cr) is widely distributed in the earth's crust and in undisturbed systems is more abundant than cobalt (Co), Cu, Zn, molybdenum (Mo), Pb, nickel (Ni), and Cd. Chromium in the form of trivalent chromium (Cr^{+3}) primarily occurs in nature as chromite with the formula (Fe, Mg)O(Cr, Al, $Fe)_2O_3$ and is essentially insoluble. Naturally occurring minerals of hexavalent chromium (Cr^{+6}) are very rare and found only in highly oxidizing environments at low concentrations. Most environmental concentrations of Cr^{+6} are the result of industrial and domestic emissions (Cary *et al.* 1977, NJ DEP 1995, Bodek *et al*. 1988, Faust and Aly 1981).

The average Cr concentration in the continental crust is 125 parts per million (ppm) and ranges between 80 to 200 ppm. Chromium occurs in soils at concentrations ranging from trace amounts to greater than 10,000 ppm. A geometric mean of Cr in soils in the United States was estimated to be 37 ppm. Higher concentrations of Cr can be found in ultramafic igneous rocks (1,000 – 3,400 ppm), in shales and clays (30 – 590 ppm), and in phosphorites (30 – 3,000 ppm) (Faust and Aly 1981).

Chromium can exist in oxidation states ranging from Cr^{-2} to Cr^{+6}, but it is most frequently converted to the relatively stable Cr^{+3} and Cr^{+6} oxidation states (Eisler 1986a). In both freshwater and marine systems, hydrolysis and precipitation are the most important processes that determine the fate and effects of Cr; whereas, adsorption and bioaccumulation are relatively minor. Precipitated Cr^{+3} hydroxides remain in sediments under aerobic conditions. However, under anoxic and low pH conditions, Cr^{+3} hydroxides may solubilize and remain as ionic Cr^{+3} unless oxidized to Cr^{+6} through mixing and aeration (Eisler 1986a). In soils, the solubility and bioavailability of Cr are governed by soil pH and organic complexing substances, although organic complexes play a more significant role (James and Bartlett 1983a, 1983b).

The trivalent state is the form usually found in biological materials. This form functions as an essential element in mammals by maintaining efficient glucose, lipid, and protein metabolism (Steven *et al.* 1976). Chromium is beneficial but not essential to higher plants (Eisler 1986a). The biomagnification and toxicity of Cr^{+3} is low relative to Cr^{+6} because of its low membrane permeability and its noncorrosivity. However, a large degree of accumulation by aquatic and terrestrial plants and animals in the lower trophic levels has been documented (Eisler 1986a), although the mechanism of accumulation remains largely unknown.

Bodek, I, W.J. Lyman, W.F. Reehl, and D.H. Rosenblatt (eds). 1988. In: Environmental Inorganic Chemistry: Properties, Processes and Estimation Methods, Pergamon Press, New York.

Cary, E.E., W.H. Allaway, andO.E. Olson. 1977. Control of Chromium Concentrations in Food Plants. 2. Chemistry of Chromium in Soils and Its Availability to Plants. J. Agric Food Chem., Vol 25, No.2, pp 305-309.

Eisler, R. 1986a. “Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.” U.S. Fish and Wildlife Service Biological Report, 85(1.86). 60 p.

Faust, S.D. and O.S. Aly. 1981. In: Chemistry of Natural Waters, Butterworth Publishers, Woburn, MA. 1981. 400p.

James, B.R. and R.J. Bartlett. 1983a. "Behavior of Chromium in Soils: V. Fate of Organically Complexed Cr (III) Added to Soil." *J. Environ. Qual.*, 12:169-172 In: Eisler, R. 1986. "Chromium Hazards to Fish, Wildlife, and Invertebrates: a Synoptic Review." *U.S. Fish and Wildlife Service Biological Report*, 85(1.86). 60p.

New Jersey Department of Environmental Protection (NJ DEP). 1995. Basis and Background. Derivation of an Ecological-Based Soil Screening Level for Trivalent Chromium. Site Remediation Program, Trenton, N.J. 20pp. July 1995.

James, B.R. and R.J. Bartlett. 1983b. "Behavior of Chromium in Soils: VI. Interactions Between Oxidation-Reduction and Organic Complexation." *J. Environ. Qual.*, 12:169-172 In: Eisler, R. 1986. "Chromium Hazards to Fish, Wildlife, and Invertebrates: a Synoptic Review." *U.S. Fish and Wildlife Service Biological Report*, 85(1.86). 60p.

Steven, J.D., L.J. Davies, E.K. Stanley, R.A. Abbott, M. Inhat, L. Bidstrup, and J.F. Jaworski. 1976. “Effects of chromium in the Canadian environment.” *Nat. Res. Counc. Can.*, NRCC No. 15017. 168 p.

A.4 Copper

Copper does not appear to have mutagenic properties, but is a teratogen (RTECS 1991) and a possible carcinogen (Venugopal and Luckey 1978). Copper is caustic, and acute toxicity is primarily related to this property (Hatch 1978).

Copper is an essential element for animals and is a component of many metalloenzymes and respiratory pigments (Demayo *et al.* 1982). It is also essential to Fe utilization and functions in enzymes for energy production, connective tissue formation, and pigmentation (Venugopal and Luckey 1978). Excess Cu ingestion leads to accumulation in tissues, especially in the liver. High levels of Cu modify hepatic metabolism (Brooks 1988), which may lead to inability of the liver to store and excrete additional Cu. When liver concentration exceeds a certain level, the metal is released into the blood, causing hemolysis and jaundice. High Cu levels also inhibit essential metabolic enzymes (Demayo *et al.* 1982). Toxic symptoms appear when the liver accumulates three to 15 times the normal level of Cu (Demayo *et al.* 1982).

Although the exact mechanism of toxicity is not known, the following mechanisms have been proposed: Formation of stable inhibitory complexes with cytochrome P-450 (Wiebel *et al.* 1971); impairment of function of NADPH-cytochrome c reductase and alteration of mixed function oxidations (Reiners *et al.* 1986); and inhibition of heme biosynthesis (Martell 1981). Intranuclear inclusions may act as a detoxifying mechanism where Cu is complexed by protein ligands, protecting cytoplasmic organelles (Demayo *et al.* 1982).

Brooks, L. 1988. "Inhibition of NADPH-cytochrome c reductase and attenuation of acute diethylnitrosamine hepatotoxicity by copper." Ph.D. Dissertation, Rutgers University, New Brunswick, N.J.

Demayo, A., M.C. Taylor and K.W. Taylor. 1982. Effects of copper on humans, laboratory and farm animals, terrestrial plants and aquatic life. *CRC Critical Reviews in Environmental Control.* 12(3):183-255.

Hatch, R.C. 1978. Poisons Causing Respiratory Insufficiency. *In: Veterinary Pharmacology and Therapeutics.* L.M. Jones, N.H. Booth and L.E. McDonald (eds.). Ames Press, Iowa State University. Ames, Iowa.

Martell, A.E. 1981. Chemistry and Metabolism of Metals Relevant to their Carcinogenicity. *Environmental Health Perspectives,* 40:27-34.

Reiners, J.J., E. Brott and J.R.J. Sorenson. 1986. Inhibition of Benzo(a)pyrene-dependant Mutagenesis and Cytochrome P-450 Reductase Activity by Copper Complexes. *Carcinogenesis,* 7:1729-1732.

RTECS (Registry of Toxic Effects of Chemical Substances) Database. 1991. Published by the National Institute for Occupational Safety and Health (NIOSH).

Venugopal, B. and T.D. Luckey. 1978. Metal Toxicity in Mammals: 2. Chemical Toxicity of Metals and Metalloids. Plenum Press, New York, NY.

Wiebel, F.J., J.C. Leutz, L. Diamond and H.V. Gelboin. 1971. Aryl Hydrocarbon (Benzo(a)pyrene) Hydroxylase in Microsomes from Rat Tissues: Differential Inhibition and Stimulation by Benzoflavones and Organic Solvents. *Arch. Biochem. Biophys.,* 144:78-86.

A.5 Lead

Lead does not biomagnify to a great extent in food chains, although accumulation by plants and animals has been extensively documented (Wixson and Davis 1993, Eisler 1988b). Older organisms typically contain the highest tissue Pb concentrations, with the majority of the accumulation in the bony tissues of vertebrates (Eisler 1988b).

Predicting the accumulation and toxicity of Pb is difficult since its effects are influenced to a very large degree, relative to other metals, by interactions among physical, chemical, and biological variables. In general, organolead compounds are more toxic than inorganic Pb compounds, and young, immature organisms are most susceptible to its effects (Eisler 1988b). In plants, Pb inhibits growth by reducing photosynthetic activity, mitosis, and water absorption. The mechanism by which photosynthetic activity is reduced is attributed to the blocking of sulfhydryl groups, inhibiting the conversion of coproporphyrinogen to proporphyrinogen (Holl and Hampp 1975).

The toxic effects of Pb on aquatic and terrestrial organisms are varied and include mortality, reduced growth and reproductive output, blood chemistry alterations, lesions, and behavioral changes. However, many effects exhibit trends in their toxic mechanism. Generally, Pb inhibits the formation of heme, adversely affects blood chemistry, and accumulates at hematopoietic organs (Eisler 1988b). At high concentrations near levels causing mortality, marked changes to the central nervous system occur prior to death (Eisler 1988b).

Plants can uptake Pb through surface deposition in rain, dust, and soil, or through the roots. The ability of a plant to uptake Pb from soils is inversely related to soil pH and organic matter content. Lead can inhibit photosynthesis, plant growth, and water absorption.

Eisler, R. 1988b. *Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Biological Report, 85(1.14). 134p.

Holl, W. and R. Hampp. 1975. Lead and Plants. *Residue Rev.*, 54:79-111.

Wixson, B.G. and B.E. Davis. 1993. Lead in Soil. Lead in Soil Task Force, Science Reviews, Northwood. 132pp.

A.6 Manganese

Manganese does not occur as a free metal in the environment but is a component of numerous minerals. Elemental Mn and inorganic Mn compounds have negligible vapor pressures, but may exist in air as suspended particulate matter derived from industrial emissions or the erosion of soil. Removal from the atmosphere is mostly through gravitational settling. The transport and partitioning of Mn in water are controlled by the solubility of the specific chemical form present. The metal may exist in water in any of four oxidation states; Mn^{2+}, Mn^{3+}, Mn^{4+}, and Mn^{7+}. Divalent manganese (Mn^{+2}) predominates in most waters (pH 4 to 7), but may become oxidized at a pH greater than 8 or 9. Manganese is often transported in moving water adsorbed to suspended sediment. The tendency of soluble Mn compounds to adsorb to soils and sediments depends mainly on the CEC. The CEC is related to a soil's organic content and texture; CEC increases with organic matter content, increasing pH, and in finer textured soils. Adsorption of Mn and other metals to soil colloid particles increases with increasing CEC. Manganese in water may be significantly bioconcentrated at lower trophic levels. However, biomagnification in the food chain may not be significant (ATSDR 1990b).

ATSDR (Agency for Toxic Substances and Disease Registry). 1990b. *Toxicological Profile for Manganese.* Report prepared by the Research Triangle Institute for the U.S. Department of Health and Human Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA.

A.7 Nickel

Pure Ni is a hard, white metal that is used in the formation of alloys (such as stainless steel), and it is found in all soils. Nickel is the twenty-fourth most abundant element and is found in the environment as oxides or sulfides. It may be released into the environment through mining, oil-burning power plants, coal-burning power plants, and incinerators. Nickel will attach to soil or sediment particles, especially those containing Fe or Mn. Under acidic conditions, Ni may become more mobile and seep into the groundwater. The typical Ni concentration reported in soils is from 4 to 80 milligram per kilogram (mg/kg). The speciation and physicochemical state of Ni is important in considering its behavior in the environment and its availability to biota (ATSDR 1996).

ATSDR (Agency for Toxic Substances and Disease Registry). 1996. *Toxicological Profile for Nickel.* Report prepared by the Research Triangle Institute for the U.S. Department of Health and Human Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA.

A.8 Silver

Silver (Ag) is a rare element, but occurs naturally in the environment. Silver is used to make jewelry, silverware, electronic equipment, and dental fillings. Photographic materials are the primary source of Ag release into the environment. Other sources include mining operations and the natural weathering of Ag-bearing rocks and soil by wind and rain. Silver that is released into the environment may be carried long distances in air and water. Rain can wash Ag compounds out of the soil and into the groundwater. Silver does remain stable in the environment in various forms. It does not break down and can change its form by combining with other substances.

Silver concentrations in natural waters are usually very low, and if acute toxicity is ameliorated, there lies a possibility for accumulation of the metal. In laboratory experiments, Ag was bioconcentrated to a degree by all trophic levels tested. The BCFs for the aquatic organisms tested were *Daphnia magna* (61.0) > *Lemna gibba* (25.4) > *Selenastrum capricornutum* (4.8) > *Lepomis macrochirus*, internal organs (0.06) > *L. macrochirus*, gills (0.03). Significant Ag concentrations were not transferred to higher trophic levels in any of these experiments. These data suggest that the chance for biomagnification of Ag in aquatic systems is small (Forsythe 1996).

No information on the bioavailability or bioconcentration of Ag in terrestrial systems could be found at the writing of this report.

Forsythe, B.L. II. 1996. " Silver in a freshwater ecosystem: acute toxicity and trophic transfer." Ph.D. Dissertation, Clemson University, North Carolina

A.9 Zinc

Zinc occurs naturally in the earth's crust with an average concentration of 70 mg/kg. Zinc compounds are not found free in nature, but often occur in the +2 oxidation state as zinc sulfide, zinc carbonate or zinc oxide. The primary anthropogenic sources of Zn in the environment are from metal smelters or mining activities (HSBD 1999).

Zinc compounds are expected to exist in the particulate phase in the atmosphere, and be physically removed from the air by wet or dry deposition.

The Zn concentration of uncontaminated soils ranges from 10 to 300 mg/kg (ATSDR 1993). Zinc is strongly adsorbed to soil at pH 5 or greater, and Zn compounds have low mobility in most soils (Blume and Brummer 1991). Clay minerals, hydrous oxides, and pH are the most important factors controlling Zn solubility in soils. Soluble forms of Zn are readily absorbed by plants; normal Zn concentrations in plants range from 15 to 100 mg/kg (Kabata-Pendias and Pendias 1991; Thomas 1991). Volatilization from soil or water surfaces is not expected to be an important environmental fate process.

In surface waters, Zn can be found in several forms, including hydrated ions, metal-organic complexes or metal-inorganic complexes. Zinc is expected to adsorb to suspended solids in water and be transported to sediment (Callahan 1979).

Zinc is essential for normal growth and reproduction in plants and animals and is regulated by metallothioneins. Metallothioneins act as temporary Zn storage sites and aid in reducing the toxicity of Zn in both vertebrates and invertebrates (Olsson *et al.* 1989). Zinc is not known to bioaccumulate in food chains, because it is regulated by the body and excess Zn is eliminated.

Zinc has its primary metabolic effect on Zn-dependant enzymes that regulate the biosynthesis and catabolic rate of RNA and DNA. High levels of Zn induce Cu deficiency and interfere with metabolism of Ca and Fe (Goyer 1986). The pancreas and bone seem to be the primary targets of Zn toxicity in birds and mammals. Pancreatic effects include cytoplasmic vacuolation, cellular atrophy, and cell death (Lu and Combs 1988; Kazacos and Van Vleet 1989). Zinc preferentially accumulates in bone, and induces osteomalacia, a softening of bone caused by a deficiency of Ca, P and other minerals (Kaji *et al.* 1988). Gill epithelium is the primary target site in fish. Zinc toxicosis results in destruction of gill epithelium and tissue hypoxia (Spear 1981).

ATSDR. 1993. *Toxicological Profile for Zinc.* Report prepared by the Research Triangle Institute for the U.S. Departrment of Health and Human Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA.

Blume, H.P. and G. Brummer. 1991. Ecotox. Environ. Safety. 22:164-174. *As cited in HSDB.*

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Goyer, R.A. 1986. Toxic Effects of Metals. Pages 582-635 <u>in</u> C.D. Klaussen, M.O. Amdur, and J. Doull, editors. Casarett and Doull's Toxicology. Third Edition. Macmillan, New York. In: Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Report No. 26. 106p.

HSDB. 1999. (Hazardous Substances Data Bank). http://toxnet.nlm.nih.gov/. October 8 2003.

Kabata-Pendias, A. and H. Pendias. 1991. *Trace Elements in Soils and Plants*. 2nd Edition. CRC Press, Boca Raton, FL.

Kaji, T., R. Kawatani, M. Takata, T. Hoshino, T. Miyahara, H. Konzuka, and F. Koizumi. 1988. The Effects of Cadmium, Copper or Zinc on Formation of Embryonic Chick Bone in Tissue Culture. *Toxicology* 50:303-316. In: Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Report No. 26.

Kazacos, E.A. and J.F. Van Vleet. 1989. Sequential Ultrastructural Changes of the Pancreas in Zinc Toxicosis in Ducklings. American Journal of Pathology 134:581-595. In: Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Report No. 26. 106p.

Lu, J. and G.F. Combs. 1988. Effects of Excess Dietary Zinc on Pancreatic Exocrine Function in the Chick. *J. Nutrition* 118:681-689. In: Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Report No. 26. 106p.

Olsson, P.E., M. Zafarullah, and L. Gedamu. 1989. A Role of Metallothionen in Zinc Regulation after Oestradiol Induction of Vitellogenin Synthesis in Rainbow Trout, *Salmo gairdneri*. *Biochemical Journal* 257:555-559. In: Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Report No. 26. 106p.

Spear, P.A. 1981. Zinc in the Aquatic Environment: Chemistry, Distribution, and Toxicology. National Research Council of Canada Publication. NRCC 17589. 145p. In: Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Report No. 26. 106p.

Thomas, D.W. 1991. *Pages 1309-1342 in:* Metals and Their Compounds in the Environment. Merian, E. (Ed.). Weinheim, Fed. Rep. Ger. *As cited in HSDB.*

Lead toxicity to birds – Acute

Field Studies

Lead concentrations and physiological characteristics of blood were compared in moribund tundra swans captured in the Coeur d'Alene Basin, swans caught in swim-in traps in the contaminated area, and swans captured in reference areas (Blus *et al.* 1999). Blood lead concentrations were highest in moribund birds (3.3 µg/g in 1987 and 1995), intermediate in birds trapped in the contaminated area (0.82 µg/g in 1987 and 1.8 µg/g in 1995) and lowest in reference birds (0.11 µg/g). Of the 19 swans found moribund in the contaminated area, necropsy revealed that 18 had signs of lead poisoning. Only one of these birds contained ingested lead shot. No co-located sediment samples were collected.

Wood ducks were collected from a contaminated area in the Coeur d'Alene River basin and a reference area (Blus *et al.* 1993). Livers and ingesta from the upper gastrointestinal tract were analyzed for lead. Mean (and range) lead concentrations measured in livers of wood ducks collected from the contaminated area were: 5.1 mg/kg wet weight (2.0 – 14.4 mg/kg ww; birds killed while incubating); 2.9 mg/kg ww (1.7 – 4.5 mg/kg ww, birds found dead in traps); and 1.0 mg/kg ww (0.3 – 9.5 mg/kg ww; birds trapped and killed). Lead was not detected in livers from wood ducks collected from the reference area. The mean (and range) lead concentration in ingesta from birds collected from the contaminated area was 39.7 mg/kg ww (0.9 – 610 mg/kg ww), compared to a mean concentration of 0.32 mg/kg ww (0.18 – 0.64 mg/kg ww) found in ingesta from birds collected at the reference area. No co-located sediment samples were collected.

A waterfowl die-off of considerable magnitude was observed in the lower Couer d'Alene Valley in 1954 (Chupp and Dalke 1964). In the spring of 1955, the area was surveyed, and sick or dying birds were collected. Liver tissue from five sick whistling swans was analyzed; mean lead concentration was 28.4 mg/kg ww, and ranged from 18 to 37 mg/kg ww. Five healthy birds were collected, one merganser, three American widgeons, and one mallard. Lead was not detected in livers from four of the birds. The mallard had a liver lead concentration of 12 mg/kg ww. Soil and plant samples were collected from this area in late summer of 1962. Mean (and range) lead concentrations were 2905 mg/kg (150 to 9600 mg/kg) and 2533 mg/kg (1500 to 3700 mg/kg) in soil and plant samples, respectively.

Causes of mortality and lead and cadmium concentrations of 46 tundra swans were investigated (Blus *et al.* 1991). Thirty eight of the swans were collected from the Couer d'Alene River system, and five were collected from a relatively uncontaminated area. Of the 36 swans collected from the contaminated area, 32 had liver lead concentrations considered lethal (6.4 to 40 µg/g wet weight), and all exhibited symptoms of lead poisoning such a enlarged gall bladders containing viscous, dark-green bile. The mean lead concentration in ingesta removed from the upper gastrointestinal tract of birds collected in the Coeur d'Alene River system was 30.6 µg/g wet weight (range 0.70 to 312 µg/g wet weight). Mean lead concentration in ingesta from birds collected from the uncontaminated area was 2.3 µg/g wet weight (range 2.1 to 2.6 µg/g wet weight).

Laboratory studies

Day-old chicks were fed diets containing 0 or 2000 mg/kg lead (as lead acetate) for 21 days (Cupo and Donaldson 1988). Growth was significantly decreased in the chicks fed the lead-supplemented diet, and 18.3 % mortality was observed in this group. A body weights of 0.201 kg (cited by authors for 14-day old birds) and a food ingestion rate of 0.0193 kg/day (U.S. EPA 1988) was used to convert the exposure dose to units of mg/kgBW/day. An exposure concentration of 192 mg/kgBW/day was lethal to chicks in this experiment. This article provided no information regarding when during the experiment mortality occurred, so this study could not be used to develop an acute toxic exposure concentration for birds.

Pigeons were trained to peck a response key under a multiple fixed-ratio, fixed interval schedule of food presentation (Barthalmus *et al.* 1977). When rates of responding stabilized, birds received lead acetate at concentrations of 0, 6.25, 12.5, or 25 mg/kgBW/day administered by gastric intubation. The 25 mg/kgBW/day dose decreased rates of response after 3 to 10 days of exposure. Three of seven birds died between day 18 and 35 of the experiment. Since mortality was only observed late in the experiment, this study was not used to derive an acute TRV for lead.

Adult mallards were exposed to sediment collected from the Coeur d'Alene River basin via the follwing diets: commercial duck mash with 24% uncontaminated sediment (control birds); commercial duck mash with 24% lead-contaminated sediment (mean measured concentration of 954 mg/kg lead); or ground corn with 24% lead-contaminated sediment (mean measured concentration of 869 mg/kg lead) for 15 weeks (Heinz *et al.* 1999). Four of five birds fed the corn diet with the lead-contaminated sediment died during the experimental period. None of the ducks fed the nutritionally-balanced commercial diet and the contaminated sediment died. Renal inntranuclear inclusion bodies were observed in 90% of the birds exposed to lead-contaminated sediment. None were observed in the control birds. A body weight of 1.21 kg (presented by authors) and a food ingestion rate of 0.139 kg/day (Piccirillo and Quesenberry 1980) was used to convert the exposure concentration to units of mg/kgBW/day). The actual sediment ingestion rate measured for the lead-exposed birds fed a corn diet was 14% (contaminated "food" ingestion rate of 0.0195 kg/day). An exposure concentration of 14 mg/kgBW/day was lethal to mallards. However, the birds died on days 67, 76, 83 and 95 of the experiment, so this study was not used to derive an acute TRV for exposure of birds to lead.

Day-old mallard ducklings were fed diets supplemented with lead-contaminated sediment at lead concentrations of 1.9 (control diet), 414 and 828 μg/g lead for 6 weeks (Hoffman *et al.* 2000). A clean sediment-supplemented control (24 percent sediment) and a positive control diet containing lead acetate at a concentration equivalent to the 828 μg/g lead-contaminated sediment diet were included in the experimental design. Mortality was observed only in the lead acetate group; one of fifteen ducklings died during the fifth week of the experiment. A food ingestion rate of 0.0645 kg/day and body weight of 0.379 kg (cited by (Sugden *et al.* 1981) for three-week old mallard ducklings) were used to convert the exposure concentrations to units of mg/kgBW/day. An exposure concentration of 140.9 mg/kgBW/day was lethal to mallard ducklings in this experiment. However, since no mortality was observed until the fifth week of exposure, this study was not used to derive an acute TRV for lead.

Six week old chickens were dosed with lead acetate dissolved in water at concentrations of 0, 20, 40, 80, 160, 320 or 640 mg/kgBW/day for 35 days (Vengris and Mare 1974). Doses as high as 160 mg/kgBW/day were tolerated with no clinical signs or hematological changes observed. There was 50% and 92% mortality observed in the groups exposed at the two highest exposure concentrations, respectively. In the 320 mg/kgBW/day exposure group, one chicken died on the 11^{th} day of the experiment, and five others died after 21 to 30 days of exposure. In the 640 mg/kgBW/day exposure group, the first chicken died on the sixth day of lead exposure and the last one on day 34. An exposure concentration of 640 mg/kgBW/day was identified as an acutely toxic TRV for birds based on results of this experiment.

Barthalmus, G. T., G. T. Leander, J. D. McMillan, M. P. and M. R. Krigman. 1977. Chronic effects of lead on schedule-controlled pigeon behavior. Toxicol. Appl. Pharmacol. 42: 271-284.

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Blus, L. J., C. J. Henny, D. J. Hoffman and R. A. Grove. 1993. Accumulation and effects of lead and cadmium on wood ducks near a mining and smelting complex in Idaho. Ecotoxicology 2: 139-154.

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Heinz, G. H., D. J. Hoffman, L. Sileo, D. J. Audet and L. J. LeCaptain. 1999. Toxicity of lead-contaminated sediment to mallards. Arch Environ. Contam. Toxicol. 36: 323-333.

Hoffman, D. J., G. H. Heinz, L. Sileo, D. J. Audet, J. K. Campbell and L. J. LeCaptain. 2000. Developmental toxicity of lead-contaminated sediment to mallard ducklings. Arch Environ. Contam. Toxicol. 39: 221-232.

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Sugden, L. G., E. A. Driver and M. C. S. Kingsley. 1981. Growth and energy consumption by captive mallards. Can. J. Zool. 59: 1567-1570.

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Toxicity Reference Value for Acute Sediment Ingestion of Lead

Results from studies on waterfowl experimentally fed lead-contaminated sediment were combined with results from field studies in an attempt to relate sediment lead concentrations to adverse effects on waterfowl (Beyer *et al.* 2000). Based on field studies, the exposure of waterfowl to lead is proportional to the concentration of sediment ingested with the diet (Beyer *et al.* 1997; Beyer *et al.* 1998; Beyer *et al.* 1999). At contaminated sites, the relative amount of lead in prey or vegetation is minor compared to the lead in sediment incidentally ingested by waterfowl while feeding.

Although sediment ingestion rates vary among individuals and species, a single sediment ingestion rate was specified for the model. For the analysis in this study, swans were selected as the exposure species. Swans are relatively susceptible to lead poisoning, and they ingest large quantities of sediment as they feed (Beyer *et al.* 2000). Using fecal samples collected from the Coeur d'Alene River Basin, a sediment ingestion rate at the 90th percentile was selected as the exposure level of concern; this corresponded to a sediment ingestion rate of 22%.

Numerous laboratory studies have been conducted using waterfowl fed sediment from the Coeur d'Alene River Basin (Heinz *et al.* 1999; Hoffman *et al.* 2000a; Hoffman *et al.* 2000b; Day *et al.* 2003; Parker *et al.* 2003). Results from these studies provide an extensive database for relating sediment lead concentrations to observed adverse effects. Blood lead concentrations and dietary lead concentrations from the various experiments were plotted; the relationships were linear, but the slope of the line was species-dependent. For swans ingesting sediment at the 90th percentile rate (22%), the blood lead concentration is approximately the sediment lead concentration divided by a thousand.

Blood lead concentrations were measured in tundra swans found moribund from lead poisoning in the Coeur d'Alene Basin; no lead shot were found in the swans gizzards or intestinal tracts (Blus *et al.* 1991; Blus *et al.* 1999). Using the fifth percentile of blood lead concentration from the moribund swans, it can be concluded that some swan mortality would occur at a blood lead concentration of 1.9 mg/kg. The mean blood lead concentration of the moribund swans was 3.6 mg/kg. Using the above relationship between dietary lead and blood lead concentrations in swans, it can be concluded that some mortality may occur in swans exposed to sediment lead concentrations of 1800 mg/kg, and that half of exposed swans will die if ingesting sediment with a lead concentration of 3600 mg/kg.

The authors note that the relationship between sediment lead concentration and blood lead concentration is site-specific, and depends on the species present, the sediment ingestion rate, and the bioavailability of the lead in the sediment. The laboratory studies indicate that the lead in sediment collected from the Coeur d'Alene River Basin is about half as biologically available as lead acetate in the diet. Lead acetate fed to animals in laboratory studies is considered 100% bioavailable.

The results of the above analysis will be used to evaluate toxicity of lead in sediment to semipalmated plovers for this risk assessment. Swans are relatively susceptible to lead poisoning, so they can be used as a conservative surrogate for shorebirds. The mean and 90th percentile sediment ingestion rates reported for tundra swans are 9 and 22%, respectively (Beyer *et al.* 1998). Sediment ingestion rates reported for shorebirds range from 7.5 to 30%, indicating high incidental ingestion of sediment by these birds while feeding (Beyer *et al.* 1994; Hui and Beyer 1998). A sediment concentration of 3600 mg/kg will be considered acutely toxic to 50% of the semipalmated plovers and a sediment concentration of 2,370 mg/kg will be considered acutely toxic to 20% of the plovers.

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Life History Characteristics of Biota

An overview of the biological and pertinent life history characteristics of the prevalent and/or important species associated with the intertidal zone is provided:

<u>Cordgrass (*Spartina alterniflora*)</u>

Spartina is considered a native plant to the eastern United States that readily colonizes unvegetated intertidal areas. It is perennial grass that grows from two to four feet tall. *Spartina* is deciduous with its stems dying back at the end of each growing season. It reproduces by both seed and vegetative growth. Seeds are important for colonizing new areas, but the expansion of established stands is primarily due to vegetative growth. It expands via underground rhizomes often more than three feet per year.

Spartina is of major ecological importance as a habitat for fish, birds, mammals and invertebrates and as a primary producer of organic matter for coastal food chains. It is also used for preventing soil erosion and restoring wetlands along coastal areas.

Several investigations have published on the ability of *Spartina* to accumulate metals including As, Pb, Cu, Fe, Mn and Zn (Cambrolle 2008, Carbonell-Barrachina 1998, Windhams 2001). *Spartina* are able to accumulate metals in their roots, blades and seeds.

<u>Ribbed Mussel (*Geukensia demissa*)</u>

The ribbed mussel is a bivalve mollusk that is relatively large growing to 10 cm in length. The bivalve shell is grooved with obvious ribs from which its name is derived. It is a filter feeder that draws water over its gills where particles are either selected for and passed into the digestive system or selected against and passes out as pseudofeces. Ribbed mussels are able to forage on small sized bacterioplankton. Ribbed mussels feed only when submerged at high tide. At low tide, the shells remain closed to conserve water. Some mussels filter 10 gallons (4.5 liters) of seawater per day to obtain enough food.

Ribbed mussels attach by bysal threads to any hard surface like oyster shells or *Spartina* (cordgrass) stalks at the Laurence Harbor site. The ribbed mussels do not burrow completely into the sediment but remain partially exposed. Ribbed mussels can be found throughout the low to mid intertidal elevations. Upper intertidal limits are determined by both exposure to high temperatures and limited food availability during the longer periods of tidal exposure. Lower intertidal limits are determined by the availability of effective refuge, mainly from crab predators.

Ribbed mussels establish habitat among the root structure of cordgrass (*Spartina alterniflora*) that subsequently provides essential nutrients enhancing the plant's growth. Mussel beds can also provide support and stability for the root system of *Spartina* allowing the plant to withstand harsh storms or ice conditions.

Section 4 of this report provides a characterization of the ribbed mussels collected within the intertidal zone for the Laurence Harbor site providing the size range of the ribbed mussels collected and their bioaccumulation potential of the metal contaminants.

<u>Long Neck Clam (*Mya arenaria*)</u>

Mya arenaria, commonly called long neck clam or soft shell clam, lives in burrows up to 30 cm or more deep in sand mud and sandy gravels from the mid shore to the shallow sublittoral. This clam has siphons that are fused into a rigid process that is too large to be completely withdrawn into the shell. The siphon is capable of great elongation that will extend its long siphon to the surface of the sediment to filter plankton and water. It is the clam that can often be observed squirting water from the burrows. Juvenile clams are up to 12 mm in size that tend to move about on the substrate and only burrows down to 1 to 2 cm and hence are often exposed to wave action. Young long neck clams can achieve a length of 30 mm by the first year. Maturity may be achieved in five years and the clams may reach 150 mm at an age of eight years. Adult clams can burrow as far as 30 cm into the sediments with the siphonal process extending to the sediment surface. The acceptable commercial size of 50 mm is achieved in 1.5 to 2 years.

Section 4 of this report provides a characterization of the long neck clams collected within the intertidal zone of the Laurence Harbor site that provides the size range and age of the clams and their bioaccumulation potential of the metal contaminants.

<u>Hard Clam (*Mercenaria mercenaria*)</u>

The hard clam is the most extensively distributed commercial clam in the United States. It has a thick shell with a violet border and short siphons and is found in the intertidal and subtidal areas of bays and estuaries. The mean length of the shell is 60 to 70 mm but some are 120 to 130 mm. Sexual maturity is usually reached at two years of age with the shell length of 32 to 38 mm. The peak reproductive potential is usually reached at 60 mm.

The average size female hard clam can releases 8 million eggs over a season via their excurrent siphon. Eggs are pelagic and transported via currents and tides. Spermatoza released into the water come into contact and fertilize the egg. The trochophore larvae develops within 12 to 24 hours after hatching and remains in the water column. The larvae then develops into the veliger larvae where a thin transparent shell is secreated. The veligers continue to drift with the currents and tides for a period of 6 to 30 days depending on temperature conditions. When the veliger becomes 2 to 3 mm long, the shell thickens and a foot and bysal gland develops to become a juvenile seed clam. Seed clams will find a hard substrate to attach during the first year and then will begin a final migration to their ultimate habitat. Once a desirable location is found, the young clam will attach to hard bottom (sand bed or shells) with byssal threads for about one year until the clam is about 100 mm long. The juveniles then metamorphose and assume the burrowing habits of the adults. The adult habitat is determined by where the juvenile beds are established. Adults tend to bury at a shallow depth of a couple of centimenters, but it has been reported that the hard clam can occur up to depths of 15 meters. The adult clam feeds by filtering out plankton and microorganisms that are carried along the bottom by currents.

The absence of hard clam populations is an ecological indicator of disturbances. The adult clams do not move around but stay in one place. If a hard clam bed is annihilated, the repopulation of the bed would depend on the transport of larvae and several years of growth. As a result, a temporary disturbance can cause a long term impact.

Section 4 of this report provides a characterization of the hard clams collected within the subtidal zone of the Laurence Harbor site that provides the size range and age of the clams and their bioaccumulation potential of the metal contaminants.

<u>Sea Lettuce (*Ulva*)</u>

Ulva is a green macroalgae that can grow up to 30 cm across with a broad crumbled frond that is tough, translucent and membranous. *Ulva* can be found in all intertidal zones and can be found in a variety of places ranging from exposed rocks to brackish pools. *Ulva* is often attached, but in later stages of life can be found free drifting. The holdfast is perennial and the blade of *Ulva* is annual. It is reported that worms, fish, sea slugs and birds, such as, Brant, will eat *Ulva*. *Ulva* is highly tolerant to nutrient pollution and can often grow to nuisance level that can be detrimental to other aquatic life. There are several investigations showing that *Ulva* is a good indicator of metal contaminants such as Fe, Mn, Cu, Zn, and Pb.

Horseshoe Crab (*Limulus polyphemus*)

The horseshoe crab belongs to the Phylum Arthropoda that includes lobsters, crabs, spiders, insects, and scorpions. Although the horseshoe crab looks like a crab with a hard shell and claws, it is more closely related to spiders and scorpions. It moves along the bottom using its clawed and pusher legs. As it moves, the first pair of appendages feel around for clams and worms. When food is found, it is picked up by one of the claws and moved to the gnathobases, the brisky area near the base of the walking legs where the clam or worm is torn and shred. Bits of food from the shredding process then get caught onto bristles and then pushed into the crab's mouth with degenerate appendages called chelicerae. The horseshoe crab also has a gizzard contanining sand and bits of gravel to help grind its food.

As the water temperatures rise in the Spring, adult horseshoe crabs begin to move from deeper waters in the bay or continental shelf towards the beaches to spawn. They can be seen spawning during the day or night, but most are seen spawning at night when they are protected by darkness. When the female has found a mate, the male hooks their pedipals (specialized set of claw appendages) onto the opisthosoma of the female as she heads toward the beach. Sometimes additional males will attach themselves to the male forming a chain. Once on shore, the female uses her pusher legs to form a shallow nest between four and six inches deep between high and low tide lines. The female will deposit 5 to 7 clumps of 2000 to 4000 eggs each, or up to 20,000 eggs in a spawning episode. The attached male and any satellite males move with the female as she lays each clump of eggs. The female will repeat this process several times over the spawning cycle laying 90,000 eggs or more in a season. It is estimated that less than ten of these eggs will survive to adulthood.

After fertilization, the eggs begin to develop into trilobite larvae. Miniature legs are visible inside the translucent eggs by day 5. The larvae will molt for its first time by day 6. The larvae has a yolk sac which is its source of food. By the end of the second week, the larvae have molted three more times in preparation for hatching when moisture and temperature condition are ideal. However, it could take three to four weeks or even months for the eggs to hatch. Upon hatching, the trilobite larvae dig out of the sand and are about 3 mm (1/8th inch) in size and look like a miniature adults, but lack a movable tail and functional compound eye. The baby crabs swim around for about a week absorbing the yolk sac as their digestive system develops. Around day 21 the larvae settle from the water column onto the sediments. They continue to molt into juvenile crabs that are about 6 mm in size. It is estimated that the female horseshoe crab matures in 10 to 11 years with a total length of up to 16 to 20 inches long while the male crab matures in 8 to 9 years with a total length of 13 to 16 inches. (website : www.ocean.udel.edu/horseshoecrab/History/biology.html)

Revised March 25, 2009 by K. Kracko

LIFE HISTORY OF THE CANADA GOOSE (*Branta canadensis*), dry weight version

The Canada goose is the most widespread and abundant goose in North America. It is distinguished by a black head and neck with a white chinstrap, and has a pale breast and a brown back (Peterson 1990). There are eleven recognized subspecies of Canada geese in North America, differing primarily in body size and color (U.S. Fish and Wildlife Service Division of Migratory Bird Management 2005). A complete description of the distribution and migration patterns of the different subspecies can be found in (Bellrose 1976). Males are typically larger than females with body weights reaching their maximum prior to or during the spring migration. By two months of age, young are similar to parents in size.

Canadian geese are found throughout North America. Migratory populations of Canada geese leave their breeding grounds during late summer and early autumn, returning in the spring around the time the first water is opening but well before snow cover has disappeared. Spring migrations begin later for northerly populations. The bulk of the migrants typically arrive on the summer breeding grounds three weeks after the first birds appear. Some southerly populations have become year-round residents (U.S. EPA 1993). This species establishes mating, nesting, and feeding territories. Nesting territories are well defined and strongly defended; sizes range from 0.007 to 0.931 hectares (ha) (Stokes 1979; Greer and Oneale 1994).

Canada geese are almost exclusively herbivorous and are primarily grazers. Grit is also consumed to aid in digestion. They prefer certain plant species and parts, but will change their diet according to food availability. Young and actively growing portions of plants are preferred foods, and geese also feed extensively on grain and leafy portions of agricultural crops (U.S. Fish and Wildlife Service Division of Migratory Bird Management 2005). During the fall, geese often consume green crops such as winter wheat. During winter, they consume more energy-rich foods such as corn. In late winter and early spring, green crops that are high in nutritive value constitute an important part of their diet. In some areas of the northeast U.S., geese initially consume marsh grasses (e.g. *Spartina* sp.) and rushes (*Juncus* sp.) which are high in protein. As the summer progresses, however, they feed increasingly on submerged eelgrass (*Zostera marina*) which provides more carbohydrates (U.S. EPA 1993). Due to the high fiber content of the goose diet, consumption rates are high and turnover of ingested food items is rapid. When actively feeding, individuals may defecate every three to four minutes (Owen 1980).

The breeding habitat of the Canada goose includes tundra, forest, prairies, marshes, ponds, and lakes. Most nesting sites are close to open water. Brood-rearing habitats require adequate cover, and riparian areas are used more frequently than open water areas (U.S. EPA 1993). Migratory populations of Canada geese leave their breeding grounds during late summer and early autumn, returning in the spring around the time the first water is opening but well before snow cover has disappeared. Spring migrations begin later for northerly populations. The bulk of the migrants typically arrive on the summer breeding grounds three weeks after the first birds appear. Some southerly populations have become year-round.

Canada geese display lifelong monogamy. Young geese may form pair bonds and defend territories, however the earliest breeding occurs at two years of age (U.S. Fish and Wildlife Service Division of Migratory Bird Management 2005). Most birds are three or four before mating for the first time. Nests are usually found on the ground near water. Nests are simple, usually shallow depressions lined with plant material. Canada geese display lifelong monogamy. The breeding/laying season is generally from late February into May, though Alaskan populations may breed into June. The clutch size ranges from 1 to 10 (average 4-6). Females incubate the eggs but both parents protect the nest and care for the chicks. Mated pairs only attempt to raise one brood per year, although geese that breed in southern latitudes will re-nest if a clutch is lost before incubation (U.S. EPA 1993). The incubation period is between 23 and 30 days (Dewey and Lutz 2002). Young are precocial and able to swim and feed on the first or second day after hatching (Palmer 1976).

Canada geese are long-lived birds with generally high annual survival rates. Natural predators of Canada goose eggs and goslings include skunks, coyotes, foxes, ravens, jaegers, crows, magpies, and herring gulls. Most gosling mortality occurs within the first few weeks after hatching (Bellrose 1976). Mortality among adults is primarily due to hunting and inclement weather (Bellrose 1976). One Canada goose was found dead 23 years after it was banded (Douville and Friley 1957). Another was banded and recaptured 30 years and 4 months later (Klimkiewicz 2008).

EXPOSURE PROFILE OF THE CANADA GOOSE (*Branta canadensis*)

For this risk assessment, conservative exposure parameters are the highest (ingestion rates) or lowest (body weight [BW], home range [HR] size) values located in the literature. Representative exposure parameters are the average of the values located for this species. When an allometric equation is used to calculate ingestion, representative ingestion rates (in units of amount ingested per day) are higher than conservative ingestion rates, since the corresponding BWs input into the equation are higher.

Adult Canada geese weigh from 0.95 kg (*B.c.minima*, female, hatch day of incubation, Raveling 1979) to 6.3 kg (male, season and subspecies not specified, Nelson and Martin 1953) (Poole 1938; Nelson and Martin 1953; Douville and Friley 1957; Stewart and Skinner 1967; Raveling 1968; Chapman 1970; Yocom 1972; Ratti *et al.* 1977; Raveling 1979; McLandress and Raveling 1981a; Aldritch and Raveling 1983; Joyner *et al.* 1984; Murphy and Boag 1989; Conover and Messmer 1996; Leafloor *et al.* 1998; Cummings *et al.* 2002). Body weights typically reach their maximum prior to or during the spring migration. Males are heavier than females and there is considerable variation in body weights among subspecies. A conservative body weight of 0.95 kg and a representative body weight of 3.29 kg will be used for this risk assessment. Weights of individual subspecies vary considerably—if this risk assessment is evaluating a particular subspecies, check the spreadsheet for weight range and conservative and representative values.

Dietary composition for the Canada goose is reported to be 100 percent vegetation with some grit (Glazener 1946; Craven and Hunt 1984; Prevett *et al.* 1985; Coleman and Boag 1987; Cadieux *et al.* 2005) They prefer certain plant species and parts, but will change their diet according to food availability. Young and actively growing portions of plants are preferred. Heavy utilization of grass fields was observed when protein levels and digestibility of young grass shoots were high (McLandress and Raveling 1981b). For this risk assessment, Canada geese will be assumed to be 100% herbivorous.

Food ingestion rates ranging from 0.107 to 0.213 kg/day dry weight (dw) have been reported for this species (Jordan 1953; Vaught and Kirsch 1966; Joyner *et al.* 1984; Fletcher 1987; Cummings *et al.* 1992; Cummings *et al.* 2002). A conservative food ingestion rate of 0.213 kg/day dw and a representative food ingestion rate of 0.148 kg/day dw will be used for this risk assessment.

An allometric equation developed by (Calder and Braun 1983) was used to estimate the water ingestion rate [water ingestion (L/day) = 0.059 $Wt^{0.67}$, where wt is body weight in kg). Using this equation, a conservative estimate for water ingestion is 0.057 L/day (Wt = 0.95 kg) and a representative water ingestion rate is 0.131 L/day (Wt = 3.29 kg).

Soil ingestion rates reported for this species range from less than 2% to 75.9%, with the midpoint of the reported rates being 8.68% (Connor 1993; Beyer *et al.* 1994; Beyer *et al.* 1998). Using the above food ingestion rates, a conservative soil ingestion rate of 0.162 kg/day and a representative soil ingestion rate of 0.0128 kg/day were calculated.

Home range sizes measured for female Canada geese with broods range from 290 to 2,830 hectares (Eberhardt *et al.* 1989). Sizes of actively defended nesting territories range from 0.007 to 0.931 ha (Stokes 1979; Greer and Oneale 1994).

In summary, the food chain model parameters for the Canada goose are as follows:

Conservative Scenario:

BW:	0.95 kg

[1]Total ingestion: 0.213 kg/d dry weight
[1]Food ingestion: 0.051 kg/d dw
Water ingestion: 0.057 L/d
Soil ingestion: 0.162 kg/d
HR: 290 ha

Representative Scenario:

BW:	3.29 kg
[1]Total ingestion:	0.148 kg/d dw
[1]Food ingestion:	0.1467 kg/d dw
Water ingestion:	0.131 L/day
Soil ingestion:	0.00128 kg/d
HR:	1560 ha

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Created December 2008, K. Kracko

Semipalmated plover (*Charadrius semipalmatus*); dry weight version

Life History

The semipalmated plover is a small plover with a short bill and yellow-orange legs. The name "semipalmated" refers to the partial webbing found between the bird's three front toes. It has brown upperparts with white undersides, and a single dark breast band. There is a black band on the top of the head, and a white patch between the eyes. The breastband, sides of the head, and forecrown are black in breeding adults and brown in non-breeding adults and juveniles (Bull and Farrand 1977; Nol and Blanken 1999).

Semipalmated plovers are medium- to long distance migrants between their Arctic and sub-Arctic breeding areas and their wintering areas. The highest concentrations of migrating birds are along the coasts, but they are also found at inland sites. They arrive in the U.S. by April or May, and reach their breeding grounds in May or early June. Semipalmated plovers breed in western and northern Alaska, and in low arctic and boreal areas of northern Canada. Males precede females during the northward migration, but females precede males southward. Adults migrate south two to four weeks earlier than juveniles (Hicklin 1987). They winter in the United States on the Pacific Coast from northern California to Baja California, on the Atlantic coast from southern Virginia to Florida, and locally along the Gulf Coast. Semipalmated plovers also winter along the Pacific and Atlantic coasts of Mexico, Central America, and as far south as Patagonia in South America (Nol and Blanken 1999). There is a strong fidelity to follow the same migration route and utilize the same migratory stopover sites every year (Smith and Houghton 1984).

During migration and in winter, semipalmated plovers utilize mudflats, salt marshes with mussel beds, and low-energy exposed sandy beach areas (Strauch and Abele 1979; Smith and Nol 2000). The most important wintering habitat is estuarine mudflats of coastal bays and lagoons. Breeding habitats utilized by plovers consist of dry, gravelly tundra, turf areas with scattered grasses, and sand or gravel beaches.

Breeding season for semipalmated plovers begins in early June. The nest is a shallow depression in the substrate and may be lined with small pebbles, leaves, grass or debris. The average clutch size is four eggs, and the incubation period is approximately 24 days. Both sexes participate in incubation and in caring for their chicks (Spingarn 1934; Nol and Blanken 1999). Young are precocial, and leave the nest within one day of hatching. They are able to fly at about 22 to 31 days of age. Females abandon their mate and brood about 15 days after the eggs hatch, leaving the male as the sole guardian (Nol and Blanken 1999).

During the non-breeding season, individual birds may establish and defend feeding territories. The same individual may be territorial or non-territorial; territoriality depends on environmental conditions. Territorial behavior is more likely in patchy environments where foraging sites are limited or food organisms are patchily distributed (Recher and Recher 1969). Males establish and defend nesting territories during the breeding season. Non-breeding territory sizes from 0.01 to 0.05 hectares (ha) and nesting territory sizes ranging from 0.02 to 0.6 ha have been reported (Myers *et al.* 1979; Nol and Blanken 1999).

Semipalmated plovers are visual feeders. They forage by running a short distance, halting abruptly, then pecking at the surface of the substrate. They also "foot-stir", holding one foot forward and vibrating the substrate to locate invertebrates (Nol and Blanken 1999). They often feed in small, loose groups spaced several meters apart. They can be highly selective or opportunistic feeders, depending on the location (Baker 1977; Strauch and Abele 1979). They have a small bill which allows them to capture varied but smaller prey. Average prey sizes of 0.5 millimeters (mm) (diptera larvae, molluscs; Smith and Nol 2000), 1.8 mm (mainly polychaete worms; Strauch and Abele 1979), and 5 mm (mainly diptera larvae; Baker 1977) have been reported. On intertidal mudflats, their diet is largely comprised of small polychaetes, insects, crustaceans, and molluscs (Strauch and Abele 1979; Morrier and McNeil 1991).

In years where temperatures are low during incubation, eggs may be abandoned (Nol *et al.* 1997). Predators of eggs and young include ravens, hawks, and foxes (Blanken and Nol 1998; Nol and Blanken 1999). One study found that 5 and 6 year old birds made up 15 percent (%) of the breeding population (Nol and Blanken 1999). In the wild, one banded individual survived 9 years (Nol and Blanken 1999), and another lived 8 years and 2 months (Clapp *et al.* 1982).

Exposure Profile

For this risk assessment, conservative exposure parameters are the highest (ingestion rates) or lowest (body weight [BW], home range [HR] size) values located in the literature. Representative exposure parameters are the average of the values located for this species. When an allometric equation is used to calculate ingestion, representative ingestion rates (in units of amount ingested per day) are higher than conservative ingestion rates, since the corresponding BWs input into the equation are higher.

Reported adult body weights of semipalmated plovers range from 32.2 to 69.1 grams (g) (Murray and Jehl 1964; Post and Browne 1976; Baker 1977; Strauch and Abele 1979; Alexander and Gratto-Trevor 1997; Teather and Nol 1997; Nol and Blanken 1999). A conservative body weight of 32.2 g and a representative body weight of 49.8 g will be used for this risk assessment.

Semipalmated plovers feed primarily on benthic invertebrates. Important prey items include diptera larvae, polychaete worms, copepods, amphipods, and bivalve mollusks. Consumption of horseshoe crab eggs, terrestrial insects, sand crabs, and plant seeds has also been reported (Reeder 1951; Recher 1966; Baker 1977; Hicklin and Smith 1979; Strauch and Abele 1979; Napolitano *et al.* 1992; Blanken and Nol 1998; Nol and Blanken 1999; Smith and Nol 2000). For this risk assessment, it will be assumed that the diet of a semipalmated plover is comprised of 100% benthic invertebrates.

No species-specific food ingestion rate could be located for the semipalmated plover. Conservative and representative dry matter (dry weight) ingestion rates of 7.54 and 13.56 grams per day (g/day) were calculated using an allometric equation for Charadriformes: DMI = a(grams body mass)^{b}, where a = 0.522 and b = 0.769 (Nagy 2001).

No quantitative water ingestion rates were found for this species. An allometric equation developed by Calder and Braun (1983) was used to estimate the water ingestion rate [water ingestion in liters per day (L/day) = 0.059 Wt $^{0.67}$, where wt is body weight in kilograms (kg)]. Using this equation, a conservative estimate for water ingestion is 0.0059 L/day (Wt = 32.2 g) and a representative water ingestion rate is 0.0078 L/day (Wt = 49.5 g).

A reported sediment ingestion rate could not be located for the semipalmated plover. Tsipoura and Burger (1999) found that sand comprised approximately 2% of the volume of stomach contents of semipalmated plovers collected in New Jersey. Nol and Blanken (1999) reported that sand comprised 56.4% by weight of the stomach contents of three birds collected in Manitoba. Reeder (1951) examined eight species of shorebirds, and found that the percentage of sand in the alimentary tract varied from 10 to 60% of the total contents. Beyer *et al.* (1994) reported soil ingestion rates for four sandpiper species ranging from 7.3 to 30%. Sediment ingestion rates reported for black-billed plovers and Willets were 29 and 3%, respectively (Hui and Beyer 1998). Both semipalmated plovers and black-bellied plovers are visual feeders that feed primarily by pecking at prey, rather than probing in the sediment. A conservative sediment ingestion rate of 30% and a representative ingestion rate of 17% [mean of the six values measured by Beyer *et al.* (1994) and Hui and Beyer(1998)] will be used for semipalmated plovers in this risk assessment. Calculated conservative and representative soil ingestion rates are 0.00226 kilograms per day (kg/day) and 0.00231 kg/day, respectively.

Home ranges sizes ranging from 0.01 to 0.6 ha, or from 16 to 30 linear meters (m) of shoreline have been reported for this species (Myers *et al.* 1979; Nol and Blanken 1999). A conservative home range size of 0.01 ha and a representative home range size of 0.142 ha were identified.

Conservative estimates:

Body weight:	0.0322 kg
[1]Total ingestion rate:	0.00754 kg/day
Food ingestion rate:	0.00528 kg/day
Water ingestion rate:	0.0059 L/day
Soil ingestion rate:	0.00226 kg/day
Home range:	0.01 ha

Representative Scenario:

Body weight:	0.0498 kg
[1]Total ingestion rate:	0.01356 kg/day
Food ingestion rate:	0.01125 kg/day
Water ingestion rate:	0.0078 L/day
Soil ingestion rate:	0.00231 kg/day
Home range:	0.142 ha

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[1]The total ingestion rate is the measured (laboratory or field) food ingestion rate cited in the paragraph in the exposure profile. Soil ingestion is generally measured as a percent of food ingestion. Therefore, the food ingestion rate used in the food chain models is considered to be equal to the total ingestion rate (listed above) minus the soil ingestion rate.

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